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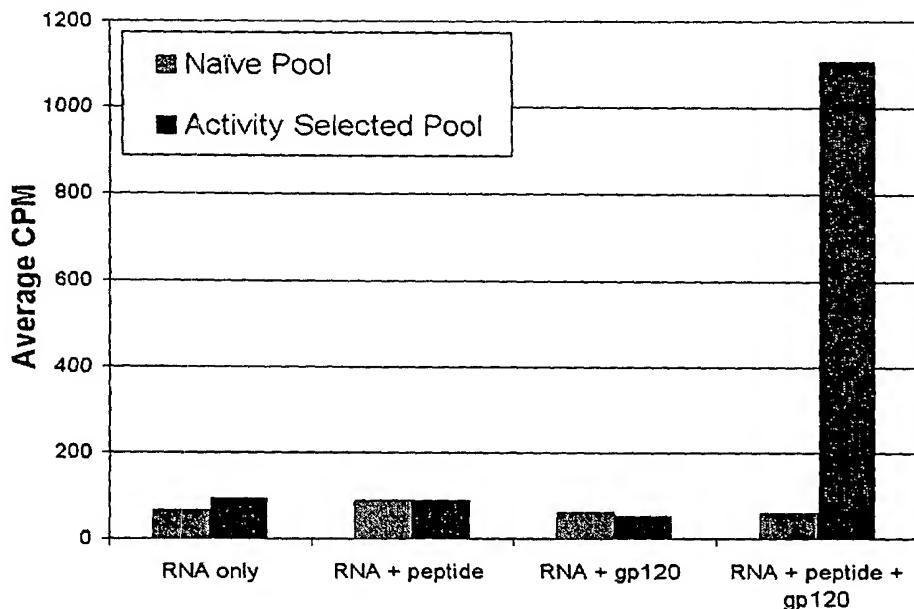
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(54) Title: PROPHYLACTIC AND THERAPEUTIC HIV APTAMERS



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(57) Abstract: Materials and methods of use thereof are presented for the prophylactic treatment of HIV. Therapeutic compositions including regulated aptamer therapeutic compositions with specificity to components of HIV disease are presented with methods of administering these therapeutic compositions as vaccines against HIV infection.



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## PROPHYLACTIC AND THERAPEUTIC HIV APTAMERS

### FIELD OF THE INVENTION

[0001] The invention relates generally to the field of nucleic acids and more particularly to compositions and methods for treating or preventing HIV with aptamers or aptamer compositions that specifically bind to gp120.

### BACKGROUND OF THE INVENTION

[0002] Aptamers are nucleic acid molecules having specific binding affinity to molecules through interactions other than classic Watson-Crick base pairing.

[0003] Aptamers, like peptides generated by phage display or monoclonal antibodies (MAbs), are capable of specifically binding to selected targets and, through binding, block their targets' ability to function. Created by an *in vitro* selection process from pools of random sequence oligonucleotides (Fig. 1), aptamers have been generated for over 100 proteins including growth factors, transcription factors, enzymes, immunoglobulins, and receptors. A typical aptamer is 10-15 kDa in size (30-45 nucleotides), binds its target with sub-nanomolar affinity, and discriminates against closely related targets (*e.g.*, will typically not bind other proteins from the same gene family). A series of structural studies have shown that aptamers are capable of using the same types of binding interactions (hydrogen bonding, electrostatic complementarity, hydrophobic contacts, steric exclusion, etc.) that drive affinity and specificity in antibody-antigen complexes.

[0004] Aptamers have a number of desirable characteristics for use as therapeutics including high specificity and affinity, biological efficacy, and excellent pharmacokinetic properties. In addition, they offer specific competitive advantages over antibodies and other protein biologics, for example:

[0005] 1) Speed and control. Aptamers are produced by an entirely *in vitro* process, allowing for the rapid generation of initial therapeutic leads. *In vitro* selection allows the specificity and affinity of the aptamer to be tightly controlled and allows the generation of leads against both toxic and non-immunogenic targets.

[0006] 2) Toxicity and Immunogenicity. Aptamers as a class have demonstrated little or no toxicity or immunogenicity. In chronic dosing of rats or woodchucks with high levels of aptamer (10 mg/kg daily for 90 days), no toxicity is observed by any clinical, cellular, or biochemical measure. Whereas the efficacy of many monoclonal antibodies can be severely limited by immune response to antibodies themselves, it is extremely difficult to elicit antibodies to aptamers (most likely because aptamers cannot be presented by T-cells *via* the MHC and the immune response is generally trained not to recognize nucleic acid fragments).

[0007] 3) Administration. Whereas all currently approved antibody therapeutics are administered by intravenous infusion (typically over 2-4 hours), aptamers can be administered by subcutaneous injection. This difference is primarily due to the comparatively low solubility and thus large volumes are necessary for most therapeutic MAbs. With good solubility (>150 mg/ml) and comparatively low molecular weight (aptamer: 10-50 KD; antibody: 150 KD), a weekly dose of aptamer may be delivered by injection in a volume of less than 0.5 ml. Aptamer bioavailability *via* subcutaneous administration is >80% in monkey studies (Tucker, 1999). In addition, the small size of aptamers allows them to penetrate into areas of conformational constrictions that do not allow for antibodies or antibody fragments to penetrate, presenting yet another advantage of aptamer-based therapeutics or prophylaxis.

[0008] 4) Scalability and cost. Therapeutic aptamers are chemically synthesized and consequently can be readily scaled as needed to meet production demand. Whereas difficulties in scaling production are currently limiting the availability of some biologics and the capital cost of a large-scale protein production plant is enormous, a single large-scale synthesizer can produce upwards of 100 kg oligonucleotide per year and requires a relatively modest initial investment. The current cost of goods for aptamer synthesis at the kilogram scale is estimated at \$500/g, comparable to that for highly optimized antibodies. Continuing improvements in process development are expected to lower the cost of goods to < \$100/g in five years.

[0009] 5) Stability. Therapeutic aptamers are chemically robust. They are intrinsically adapted to regain activity following exposure to heat, denaturants, etc. and can be stored for extended periods (>1 yr) at room temperature as lyophilized powders. In contrast, antibodies must be stored refrigerated.

[0010] The human immunodeficiency virus (HIV), the cause of acquired immunodeficiency syndrome (AIDS), remains an extremely serious threat to public health worldwide. Globally, over 40 million people are infected with HIV, with roughly 14,000 new infections arising each day (UNAIDS Report, 2002). Clearly, the best long-term solution for controlling the AIDS epidemic is development of a safe and effective HIV vaccine. The gp120 subunit is the primary viral antigen against which humoral immune responses are mounted (Profy, 1990; reviewed in Poignard *et al.*, 2001). The mature envelope glycoprotein exists as a trimer that arises through processing of a larger precursor (gp160) to gp120 and gp41 components which non-covalently associate on the virion surface (Kowalski, *et al.*, 1987; Lu *et al.*, 1995; Burton, 1997). Each gp120 monomer consists of five constant regions (C1-C5) interspersed with five variable regions (V1-V5) (Starcich *et al.*, 1986). Variable regions tend to be oriented on the outer surface of the protein where they help to shield core regions from immune surveillance. Gp120 is also heavily glycosylated (Leonard, 1990). The surface variability and glycosylation of gp120 reduce its immunogenicity. Though progress is being made in development of vaccines that stimulate cell-mediated immune responses, induction of an effective neutralizing antibody response by an HIV vaccine candidate in a clinical setting remains an urgent and unmet medical need.

[0011] Current opinion among researchers on the most efficacious route to HIV vaccine development centers on the need to induce both humoral and cell-mediated immune responses that include broadly neutralizing antibodies, and cytotoxic T-lymphocytes (CTL) and T-helper responses. The CTL cells are CD8 + and the T-helper cells are CD4+. However, vaccine-induced neutralizing antibody responses in clinical trials to date have been weak and ineffective against primary viruses.

[0012] Much recent effort has been invested in development of gp120 subunit vaccines (reviewed in Graham, 2002). However, antibodies generated against monomeric gp120 are generally not neutralizing, or at best, are capable only of neutralizing laboratory-adapted strains of HIV (Belshe *et al.*, 1994; Kahn, *et al.*, 1994) and not the more medically-relevant, primary HIV type 1 (HIV-1) isolates (Cohen, 1994). However, passive antibody studies in nonhuman primate models have shown that neutralizing

antibodies do in fact protect against infection (Prince *et al.*, 1991; Putkonen, P. *et al.*, 1991; Emini *et al.*, 1992). Indeed, antibody is the sole immune component that can neutralize virus prior to entry, unlike CTLs which are effective only after establishment of cellular infection. Induction of an effective neutralizing antibody response by a gp120-derived immunogen remains an elusive goal.

[0013] Variability of the envelope glycoprotein plays a key role in the exceptional ability of HIV to avoid immune attack. Viral mutations accumulate readily as infection progresses, generating a diverse population of variants, even within a single infected individual, and providing opportunities for escape from CTL control (Gaschen *et al.*, 2002). This diversity presents significant challenges to vaccine design. Together, surface variability and extensive glycosylation contribute to the relatively poor immunogenicity of monomeric gp120 immunogens (Leonard, 1990; Langlois *et al.*, 1998; Kwong *et al.*, 2002; Wei *et al.*, 2003). Interestingly, recent results have shown that infected individuals can and often do generate neutralizing antibody responses. Unfortunately these responses appear to lag behind the rapid evolution of the env gene and are thus unable to resist and clear the high level viremia associated with a productive infection (Wei *et al.*, 2003 and Richman *et al.*, 2003). These results do suggest however that individuals vaccinated with appropriate immunogens may be able to generate an immune response capable of protecting against the relatively low viral loads associated with initial exposure to HIV.

[0014] A variety of strategies have been developed in pursuit of effective immune responses to HIV, with testing of immunogens in a number of clinical trials (reviewed in Emini, 2002; Graham, 2002). Live-attenuated HIV vaccines have shown potential to induce protection in nonhuman primates (Nixon *et al.*, 1999). However, safety concerns have largely directed current efforts away from use of live-attenuated and whole-killed viral vaccines. Subunit vaccines, like those used in the recent Vaxgen trial, based on HIV surface proteins (primarily gp120 or gp160) though safe and generally well-tolerated, have not succeeded in eliciting neutralizing antibody responses across populations (Wantanabe, 2003). Neutralizing antibody responses against laboratory-adapted HIV strains produced by most subunit vaccines are several-fold lower than those seen during HIV-1 infection (Graham *et al.*, 2002). Type-specific neutralization can sometimes be achieved, usually corresponding to the origin of the vaccine antigen. However, neutralization of primary R5 HIV isolates has not been observed (Mascola *et al.*, 1996). Alternative vaccine concepts being evaluated in clinical trials include vectored and DNA vaccines that rely on antigen production within cells and surface display on MHC class I molecules. Emerging

evidence suggests that durable CD8+ CTL activity can be induced using these approaches (Graham *et al.*, 2002). However, as noted above, CTL-based mechanisms succeed only in eradicating cells that have already become infected. While potentially able to control viral load and attenuate disease, cell-mediated mechanisms alone are unlikely to prevent HIV infection.

[0015] Potent and enduring neutralizing antibodies are a critical component of any vaccine-induced immunity. Recently efforts have been made to design better gp120 based immunogens based upon the stabilization of conformations of gp120 known to expose neutralizing epitopes that are normally exposed only transiently during infection. The HIV entry process is complex, involving a sequence of protein-protein contacts choreographed by gp120. HIV binding interactions with CD4 receptor and with CCR5/CXCR4 co-receptors (Figure 2) each appear to be accompanied by significant structural rearrangement in gp120 (Doranz *et al.*, 1997). Initial binding of CD4 induces a conformational change in gp120 through shifting of variable loops V1 and V2 (Figure 3), thereby exposing conserved gp120 core residues that comprise the chemokine co-receptor binding site (Wu *et al.*, 1996; Trkola *et al.*, 1996). CD4-inducible (CD4i) antibodies recognizing this unmasked core region (17b, 48d) are reported to have neutralizing activity (Thali *et al.*, 1993; Sullivan *et al.*, 1998). Subsequent binding of gp120 to either CCR5 or CXCR4 stimulates a second conformational shift in gp120 that enables exposure of the fusion domain of gp41 responsible for fusion of viral and cellular membranes. In one study relying on the conformational changes associated with the HIV entry process, strong neutralizing antibody responses were generated in rhesus macaques using a covalently crosslinked gp120/CD4 complex as an immunogen (Fouts *et al.*, 2002). Unfortunately a significant portion of this effect is likely mediated by anti-CD4 antibody responses.

Another recent advance has been in the area of CD4 mimics. Using a scyllatoxin scaffold Martin *et al.* have engineered a small mini-protein that can functionally mimic that action of CD4 on gp120 (Martin *et al.*, 2003). They propose one use of this mini-protein to be as an immunogen that in conjunction with gp120 will expose the highly conserved CD4-inducible (CD4i) epitope which is normally occluded in the absence of CD4 receptor.

[0016] Several lines of biochemical and structural evidence support CD4 binding-induced structural changes in gp120, including: increased protease sensitivity of gp120 variable region loops (Sattentau *et al.*, 1991), as well as CD4-stimulated accessibility of the chemokine receptor binding site (Sattentau *et al.*, 1993; Wu, *et al.*, 1996) and of epitopes for antibodies that compete for co-receptor binding (Thali *et al.*, 1993; Zhang *et al.*, 1999).

Recent thermodynamic analysis of gp120/CD4/MAb interactions revealed unusually high changes in entropy upon CD4 binding offering further support for the hypothesis that gp120 undergoes a major conformational change upon receptor binding (Kwong *et al.*, 2002). Structural analysis of the ternary complex of CD4 and gp120 with CD4i neutralizing antibody 17b confirmed that stabilizing interactions with CD4 play a significant role in exposure or formation of the CCR5 binding region (Kwong *et al.*, 1998).

[0017] Receptor and co-receptor binding sites are attractive targets for use in vaccine design or for therapeutic intervention as they show conservation among different HIV subtypes and must be exposed on the gp120 surface, at least transiently, in order for the virus to gain entry into cells. The CCR5 binding region, in particular, is one of the most highly conserved surfaces on the gp120 core (Rizzuto *et al.*, 1998). Antibody responses to highly conserved epitopes, integral to the fundamental mechanism of HIV entry, are expected to show neutralizing activity even against diverse HIV subtypes. Thus, there is a need for a preventative, prophylactic agent that can bind specifically to gp120 and induce a conformational change that reveals suitable immunogenic epitopes and results in a humoral immune response to prevent or treat infection of cells by HIV.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0018] Figure 1 shows the *in vitro* aptamer selection (SELEX<sup>TM</sup>) process from pools of random sequence oligonucleotides.

[0019] Figure 2 shows a schematic of HIV infection of cells upon CD4-induced binding of gp120 to CCR5 membrane protein.

[0020] Figure 3 shows a schematic of HIV binding interactions with CD4 receptor and with CCR5/CXCR4 co-receptors, each of which appear to be accompanied by significant structural rearrangement in gp120.

[0021] Figure 4 shows a schematic of the steps typically required to generate an aptamer.

[0022] Figure 5 shows gp120 BaL specific binding was detectible when compared with control in a nitrocellulose binding assay.

[0023] Figure 6 shows results from a nitrocellulose filter binding assay showing binding affinity of aptamers to gp120 BaL.

[0024] Figure 7 shows results from a plate binding assay experiment using 5'-<sup>32</sup>P labeled activity selected pool (or naïve pool as a negative control) under standard selection conditions. The plot shows the counts remaining in neutravidin coated plates as a function of the presence of CCR5 peptide, gp120 BaL, both or neither component.

[0025] Figure 8 shows a schematic of an agonist (*e.g.*, a gp120 specific aptamer) inducing conformational changes in a target (*e.g.*, gp120) to facilitate a specific interaction (*e.g.*, binding) with a target partner (*e.g.*, CCR5 or CXCR4) or a target partner analog (*e.g.*, an antibody that recognizes the CCR5 or CXCR4 binding site on gp120).

[0026] Figure 9 shows a schematic of an agonist SELEX™ strategy. In this strategy, a target partner (or “TP”) or a target partner analog (or “TPA”) with agonist-independent affinity for the target is used to screen a diverse molecule library for species which can specifically interact with the TP (or TPA)-target complex. Agonist species may be specifically enriched by (1) selecting against binding to the TP/A, (2) selecting for molecules specifically retained on an immobilized TP/A-target complex, and (3) specifically released from the TP/A-target complex by known high affinity agonists.

[0027] Figure 10 shows a schematic of a second agonist SELEX™ strategy. In this strategy, a target partner or target partner analog is used to screen a diverse molecule library for species which can specifically facilitate formation of the TP (or TPA)-target complex under experimental conditions (*e.g.*, temperature, denaturant, salt concentration, target concentration, or TP/A concentration) such that agonist binding is a prerequisite for target-TP/A complex formation. Agonist species may be specifically enriched by (1) selecting against binding to TP/A and (2) selecting for molecules specifically retained only when the target is added to the immobilized TP (or TPA).

[0028] Figure 11 shows a schematic of routes to gp120 agonists, gp120:gp120 or variant (*e.g.* ΔC1ΔC5, loop truncations, etc.); CKRA: chemokine receptor or functional analog (*e.g.* neutralizing antibody 17b, detergent solubilized CCR5, CXCR4, CD4 soluble fragment of CD4 or functional analog (*e.g.* neutralizing antibody b12)); (-):negative selection step; (+):positive selection step; ():indicated component is optional for selection.

[0029] Figure 12 shows a schematic of selection pool diversification.

## SUMMARY OF THE INVENTION

[0030] A novel aspect of the current invention is the use of SELEX to isolate nucleic acids that promote specific desired conformational changes in a target of interest (“agonist SELEX”). In a preferred embodiment, the target of interest is gp120 and the desired conformational change is that which elicits an effective neutralizing antibody response by, e.g., inducing gp120 to assume and “lock” into intermediate structures present during infection. The target of interest may also be a cell surface receptor and the desired conformational change one that triggers an intracellular signaling pathway or a subunit of a viral surface molecule and the desired conformational change one that fixes the subunit in its natural structure as part of the virus.

[0031] In one embodiment, the present invention provides aptamers which bind to gp120 to cause a conformational shift in gp120 that exposes conserved epitopes on gp120 to co-receptors on cell membranes.

[0032] In one embodiment, the present invention provides aptamers which bind to gp120 to cause a conformational shift in gp120 that exposes epitopes on gp120 to CCR5 receptors.

[0033] In one embodiment, the present invention provides aptamers which bind to gp120 to cause a conformational shift in gp120 that exposes epitopes on gp120 to CXCR4 receptors.

[0034] In one embodiment, the present invention provides aptamers which bind to gp120 to cause a conformational shift in gp120 that exposes epitopes on gp120 to CCR5 and CXCR4 receptors, said CCR5 and CXCR4 binding epitopes normally blocked in the absence of binding by CD4.

[0035] In one embodiment, the present invention provides aptamers that simulate the effect of CD4 binding to gp120.

[0036] In one embodiment, the present invention provides a gp120 aptamer – gp120 conjugate that is “locked” in a conformation that presents epitopes that are able to elicit a neutralizing humoral immune response in an animal or *in vitro*.

[0037] In one embodiment, the present invention provides materials and methods of inducing a humoral immune response to gp120 by administering to subjects a gp120

aptamer-gp120 conjugate that is “locked” in a conformation that presents epitopes that are able to elicit a humoral immune response in an animal or *in vitro*.

[0038] In one embodiment, the present invention provides materials and methods of immunizing subjects against HIV infection by administering an effective amount of an aptamer which binds to gp120 to cause a conformational shift in gp120 that exposes epitopes on gp120 to CCR5 receptors.

[0039] In one embodiment, the present invention provides a method of producing neutralizing antibodies specific to gp120 by administering to a subject an aptamer-gp120 conjugate that is “locked” in a conformation that presents epitopes that are able to elicit a humoral immune response in an animal or *in vitro*.

[0040] The present invention also provides aptamer regulators that can be used, *e.g.*, to alter biological activity of a therapeutic target in response to changes in the concentration of another regulator molecule. More specifically, the present invention provides aptamers wherein binding of the aptamer to an effector ligand regulates, *i.e.*, activates or suppresses, binding of the effector ligand to a third molecule by, *e.g.*, altering the conformation of the aptamer-bound (effector) ligand.

[0041] In one embodiment, the present invention provides therapeutic aptamers whose binding activity is controlled by a first ligand which suppresses the binding activity of the therapeutic aptamer.

[0042] In one embodiment, the present invention provides therapeutic aptamers whose binding activity is controlled by a first ligand which enhances the binding activity of the therapeutic aptamer.

[0043] In one embodiment, the present invention provides therapeutic aptamers that bind to the CCR5 receptor (thus altering gp120 binding).

#### DETAILED DESCRIPTION OF THE INVENTION

##### Definitions

[0044] As defined herein, **aptamers** are nucleic acid molecules having specific binding affinity to molecules through interactions other than classic Watson-Crick base pairing.

### The SELEX<sup>TM</sup> Method

[0045] A suitable method for generating an aptamer to gp120 is with the process entitled "Systematic Evolution of Ligands by EXponential Enrichment" ("SELEX<sup>TM</sup>") generally depicted in Figure 1. The SELEX<sup>TM</sup> process is a method for the *in vitro* evolution of nucleic acid molecules with highly specific binding to target molecules and is described in, *e.g.*, U.S. patent application Ser. No. 07/536,428, filed Jun. 11, 1990, now abandoned, U.S. Pat. No. 5,475,096 entitled "Nucleic Acid Ligands", and U.S. Pat. No. 5,270,163 (see also WO 91/19813) entitled "Nucleic Acid Ligands". Each SELEX-identified nucleic acid ligand is a specific ligand of a given target compound or molecule. The SELEX<sup>TM</sup> process is based on the unique insight that nucleic acids have sufficient capacity for forming a variety of two- and three-dimensional structures and sufficient chemical versatility available within their monomers to act as ligands (form specific binding pairs) with virtually any chemical compound, whether monomeric or polymeric. Molecules of any size or composition can serve as targets.

[0046] SELEX<sup>TM</sup> relies as a starting point upon a large library of single stranded oligonucleotide templates comprising randomized sequences derived from chemical synthesis on a standard DNA synthesizer. In some examples, a population of 100% random oligonucleotides is screened. In others, each oligonucleotide in the population comprises a random sequence and at least one fixed sequence at its 5' and/or 3' end which comprises a sequence shared by all the molecules of the oligonucleotide population. Fixed sequences include sequences such as hybridization sites for PCR primers, promoter sequences for RNA polymerases (*e.g.*, T3, T4, T7, SP6, and the like), restriction sites, or homopolymeric sequences, such as poly A or poly T tracts, catalytic cores (described further below), sites for selective binding to affinity columns, and other sequences to facilitate cloning and/or sequencing of an oligonucleotide of interest.

[0047] The random sequence portion of the oligonucleotide can be of any length and can comprise ribonucleotides and/or deoxyribonucleotides and can include modified or non-natural nucleotides or nucleotide analogs. See, *e.g.*, U.S. Patent Nos. 5,958,691; 5,660,985; 5,958,691; 5,698,687; 5,817,635; and 5,672,695, PCT publication WO 92/07065. Random oligonucleotides can be synthesized from phosphodiester-linked nucleotides using solid phase oligonucleotide synthesis techniques well known in the art (Froehler *et al.*, Nucl. Acid Res. 14:5399-5467 (1986); Froehler *et al.*, Tet. Lett. 27:5575-5578 (1986)). Oligonucleotides can also be synthesized using solution phase methods

such as triester synthesis methods (Sood *et al.*, Nucl. Acid Res. 4:2557 (1977); Hirose *et al.*, Tet. Lett., 28:2449 (1978)). Typical syntheses carried out on automated DNA synthesis equipment yield  $10^{15}$ - $10^{17}$  molecules. Sufficiently large regions of random sequence in the sequence design increases the likelihood that each synthesized molecule is likely to represent a unique sequence.

[0048] To synthesize randomized sequences, mixtures of all four nucleotides are added at each nucleotide addition step during the synthesis process, allowing for random incorporation of nucleotides. In one embodiment, random oligonucleotides comprise entirely random sequences; however, in other embodiments, random oligonucleotides can comprise stretches of nonrandom or partially random sequences. Partially random sequences can be created by adding the four nucleotides in different molar ratios at each addition step.

[0049] Template molecules typically contain fixed 5' and 3' terminal sequences which flank an internal region of 30 – 50 random nucleotides. A standard (1  $\mu$ mole) scale synthesis will yield  $10^{15}$  –  $10^{16}$  individual template molecules, sufficient for most SELEX experiments. The RNA library is generated from this starting library by *in vitro* transcription using recombinant T7 RNA polymerase. This library is then mixed with the target under conditions favorable for binding and subjected to step-wise iterations of binding, partitioning and amplification, using the same general selection scheme, to achieve virtually any desired criterion of binding affinity and selectivity. Starting from a mixture of nucleic acids, preferably comprising a segment of randomized sequence, the SELEX™ method includes steps of contacting the mixture with the target under conditions favorable for binding, partitioning unbound nucleic acids from those nucleic acids which have bound specifically to target molecules, dissociating the nucleic acid-target complexes, amplifying the nucleic acids dissociated from the nucleic acid-target complexes to yield a ligand-enriched mixture of nucleic acids, then reiterating the steps of binding, partitioning, dissociating and amplifying through as many cycles as desired to yield highly specific high affinity nucleic acid ligands to the target molecule.

[0050] Within a nucleic acid mixture containing a large number of possible sequences and structures, there is a wide range of binding affinities for a given target. A nucleic acid mixture comprising, for example a 20 nucleotide randomized segment can have  $4^{20}$  candidate possibilities. Those which have the higher affinity constants for the target are most likely to bind to the target. After partitioning, dissociation and amplification, a

second nucleic acid mixture is generated, enriched for the higher binding affinity candidates. Additional rounds of selection progressively favor the best ligands until the resulting nucleic acid mixture is predominantly composed of only one or a few sequences. These can then be cloned, sequenced and individually tested for binding affinity as pure ligands.

[0051] Cycles of selection and amplification are repeated until a desired goal is achieved. In the most general case, selection/amplification is continued until no significant improvement in binding strength is achieved on repetition of the cycle. The method may be used to sample as many as about  $10^{18}$  different nucleic acid species. The nucleic acids of the test mixture preferably include a randomized sequence portion as well as conserved sequences necessary for efficient amplification. Nucleic acid sequence variants can be produced in a number of ways including synthesis of randomized nucleic acid sequences and size selection from randomly cleaved cellular nucleic acids. The variable sequence portion may contain fully or partially random sequence; it may also contain subportions of conserved sequence incorporated with randomized sequence. Sequence variation in test nucleic acids can be introduced or increased by mutagenesis before or during the selection/amplification iterations.

[0052] In one embodiment of SELEX™, the selection process is so efficient at isolating those nucleic acid ligands that bind most strongly to the selected target, that only one cycle of selection and amplification is required. Such an efficient selection may occur, for example, in a chromatographic-type process wherein the ability of nucleic acids to associate with targets bound on a column operates in such a manner that the column is sufficiently able to allow separation and isolation of the highest affinity nucleic acid ligands.

[0053] In many cases, it is not necessarily desirable to perform the iterative steps of SELEX™ until a single nucleic acid ligand is identified. The target-specific nucleic acid ligand solution may include a family of nucleic acid structures or motifs that have a number of conserved sequences and a number of sequences which can be substituted or added without significantly affecting the affinity of the nucleic acid ligands to the target. By terminating the SELEX™ process prior to completion, it is possible to determine the sequence of a number of members of the nucleic acid ligand solution family.

[0054] A variety of nucleic acid primary, secondary and tertiary structures are known to exist. The structures or motifs that have been shown most commonly to be involved in non-Watson-Crick type interactions are referred to as hairpin loops, symmetric and

asymmetric bulges, pseudoknots and myriad combinations of the same. Almost all known cases of such motifs suggest that they can be formed in a nucleic acid sequence of no more than 30 nucleotides. For this reason, it is often preferred that SELEX procedures with contiguous randomized segments be initiated with nucleic acid sequences containing a randomized segment of between about 20-50 nucleotides.

[0055] The core SELEX™ method has been modified to achieve a number of specific objectives. For example, U.S. Patent No. 5,707,796 describes the use of SELEX™ in conjunction with gel electrophoresis to select nucleic acid molecules with specific structural characteristics, such as bent DNA. U.S. Patent No. 5,763,177 describes SELEX™ based methods for selecting nucleic acid ligands containing photoreactive groups capable of binding and/or photocrosslinking to and/or photoactivating a target molecule. U.S. Patent No. 5,567,588 and U.S. Application No. 08/792,075, filed January 31, 1997, entitled "Flow Cell SELEX", describe SELEX™ based methods which achieve highly efficient partitioning between oligonucleotides having high and low affinity for a target molecule. U.S. Patent No. 5,496,938 describes methods for obtaining improved nucleic acid ligands after the SELEX™ process has been performed. U.S. Patent No. 5,705,337 describes methods for covalently linking a ligand to its target.

[0056] SELEX™ can also be used to obtain nucleic acid ligands that bind to more than one site on the target molecule, and to obtain nucleic acid ligands that include non-nucleic acid species that bind to specific sites on the target. SELEX™ provides means for isolating and identifying nucleic acid ligands which bind to any envisionable target, including large and small biomolecules including proteins (including both nucleic acid-binding proteins and proteins not known to bind nucleic acids as part of their biological function) cofactors and other small molecules. For example, see U.S. Patent No. 5,580,737 which discloses nucleic acid sequences identified through SELEX™ which are capable of binding with high affinity to caffeine and the closely related analog, theophylline.

[0057] Counter- SELEX™ is a method for improving the specificity of nucleic acid ligands to a target molecule by eliminating nucleic acid ligand sequences with cross-reactivity to one or more non-target molecules. Counter- SELEX™ is comprised of the steps of a) preparing a candidate mixture of nucleic acids; b) contacting the candidate mixture with the target, wherein nucleic acids having an increased affinity to the target relative to the candidate mixture may be partitioned from the remainder of the candidate mixture; c) partitioning the increased affinity nucleic acids from the remainder of the

candidate mixture; d) contacting the increased affinity nucleic acids with one or more non-target molecules such that nucleic acid ligands with specific affinity for the non-target molecule(s) are removed; and e) amplifying the nucleic acids with specific affinity to the target molecule to yield a mixture of nucleic acids enriched for nucleic acid sequences with a relatively higher affinity and specificity for binding to the target molecule.

[0058] One potential problem encountered in the use of nucleic acids as therapeutics and vaccines is that oligonucleotides in their phosphodiester form may be quickly degraded in body fluids by intracellular and extracellular enzymes such as endonucleases and exonucleases before the desired effect is manifest. The SELEX method thus encompasses the identification of high-affinity nucleic acid ligands containing modified nucleotides conferring improved characteristics on the ligand, such as improved *in vivo* stability or improved delivery characteristics. Examples of such modifications include chemical substitutions at the ribose and/or phosphate and/or base positions. SELEX-identified nucleic acid ligands containing modified nucleotides are described in U.S. Patent No. 5,660,985, which describes oligonucleotides containing nucleotide derivatives chemically modified at the 5' and 2' positions of pyrimidines. U.S. Patent No. 5,756,703 describes oligonucleotides containing various 2'-modified pyrimidines. U.S. Patent No. 5,580,737 describes highly specific nucleic acid ligands containing one or more nucleotides modified with 2'-amino (2'-NH<sub>2</sub>), 2'-fluoro (2'-F), and/or 2'-O-methyl (2'-OMe) substituents.

[0059] Modifications of the nucleic acid ligands contemplated in this invention include, but are not limited to, those which provide other chemical groups that incorporate additional charge, polarizability, hydrophobicity, hydrogen bonding, electrostatic interaction, and fluxionality to the nucleic acid ligand bases or to the nucleic acid ligand as a whole. Such modifications include, but are not limited to, 2'-position sugar modifications, 5-position pyrimidine modifications, 8-position purine modifications, modifications at exocyclic amines, substitution of 4-thiouridine, substitution of 5-bromo or 5-iodo-uracil; backbone modifications, phosphorothioate or alkyl phosphate modifications, methylations, unusual base-pairing combinations such as the isobases isocytidine and isoguanidine and the like. Modifications can also include 3' and 5' modifications such as capping. In preferred embodiments of the instant invention, the nucleic acid ligands are RNA molecules that are 2'-fluoro (2'-F) modified on the sugar moiety of pyrimidine residues.

[0060] The modifications can be pre- or post-SELEX process modifications. Pre-SELEX process modifications yield nucleic acid ligands with both specificity for their SELEX

target and improved in vivo stability. Post-SELEX process modifications made to 2'-OH nucleic acid ligands can result in improved in vivo stability without adversely affecting the binding capacity of the nucleic acid ligand.

[0061] Other modifications are known to one of ordinary skill in the art. Such modifications may be made post-SELEX process (modification of previously identified unmodified ligands) or by incorporation into the SELEX process.

[0062] The SELEX method encompasses combining selected oligonucleotides with other selected oligonucleotides and non-oligonucleotide functional units as described in U.S. Patent No. 5,637,459 and U.S. Patent No. 5,683,867. The SELEX method further encompasses combining selected nucleic acid ligands with lipophilic or non-immunogenic high molecular weight compounds in a diagnostic or therapeutic complex, as described in U.S. Patent No. 6,011,020. VEGF nucleic acid ligands that are associated with a lipophilic compound, such as diacyl glycerol or dialkyl glycerol, in a diagnostic or therapeutic complex are described in U.S. Patent No. 5,859,228.

[0063] VEGF nucleic acid ligands that are associated with a lipophilic compound, such as a glycerol lipid, or a non-immunogenic high molecular weight compound, such as polyalkylene glycol are further described in U.S. Patent No. 6,051,698. VEGF nucleic acid ligands that are associated with a non-immunogenic, high molecular weight compound or a lipophilic compound are further described in PCT Publication No. WO 98/18480. These patents and applications allow the combination of a broad array of shapes and other properties, and the efficient amplification and replication properties, of oligonucleotides with the desirable properties of other molecules.

[0064] The identification of nucleic acid ligands to small, flexible peptides *via* the SELEX method has also been explored. Small peptides have flexible structures and usually exist in solution in an equilibrium of multiple conformers, and thus it was initially thought that binding affinities may be limited by the conformational entropy lost upon binding a flexible peptide. However, the feasibility of identifying nucleic acid ligands to small peptides in solution was demonstrated in U.S. Patent No. 5,648,214. In this patent, high affinity RNA nucleic acid ligands to substance P, an 11 amino acid peptide, were identified.

[0065] To generate oligonucleotide populations which are resistant to nucleases and hydrolysis, modified oligonucleotides can be used and can include one or more substitute internucleotide linkages, altered sugars, altered bases, or combinations thereof. In one embodiment, oligonucleotides are provided in which the P(O)O group is replaced by

P(O)S (“thioate”), P(S)S (“dithioate”), P(O)NR<sub>2</sub> (“amide”), P(O)R, P(O)OR’, CO or CH<sub>2</sub> (“formacetal”) or 3’-amine (-NH-CH<sub>2</sub>-CH<sub>2</sub>-), wherein each R or R’ is independently H or substituted or unsubstituted alkyl. Linkage groups can be attached to adjacent nucleotide through an -O-, -N-, or -S- linkage. Not all linkages in the oligonucleotide are required to be identical.

[0066] In further embodiments, the oligonucleotides comprise modified sugar groups, for example, one or more of the hydroxyl groups is replaced with halogen, aliphatic groups, or functionalized as ethers or amines. In one embodiment, the 2’-position of the furanose residue is substituted by any of an O-methyl, O-alkyl, O-allyl, S-alkyl, S-allyl, or halo group. Methods of synthesis of 2’-modified sugars are described in Sproat, *et al.*, Nucl. Acid Res. 19:733-738 (1991); Cotten, *et al.*, Nucl. Acid Res. 19:2629-2635 (1991); and Hobbs, *et al.*, Biochemistry 12:5138-5145 (1973). The use of 2-fluoro-ribonucleotide oligomer molecules can increase the sensitivity of a nucleic acid sensor molecule for a target molecule by ten- to- one hundred-fold over those generated using unsubstituted ribo- or deoxyribooligonucleotides (Pagratis, *et al.*, Nat. Biotechnol. 15:68-73 (1997)), providing additional binding interactions with a target molecule and increasing the stability of the secondary structure(s) of the nucleic acid sensor molecule (Kraus, *et al.*, Journal of Immunology 160:5209-5212 (1998); Pieken, *et al.*, Science 253:314-317 (1991); Lin, *et al.*, Nucl. Acids Res. 22:5529-5234 (1994); Jellinek, *et al.* Biochemistry 34:11363-11372 (1995); Pagratis, *et al.*, Nat. Biotechnol 15:68-73 (1997)).

[0067] Nucleic acid aptamer molecules are generally selected in a 5 to 20 cycle procedure. In one embodiment, heterogeneity is introduced only in the initial selection stages and does not occur throughout the replicating process.

#### **Methods For Generating gp120 Aptamers**

[0068] The details of one or more embodiments of the invention are set forth in the accompanying description below. Although any methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are now described. Other features, objects, and advantages of the invention will be apparent from the description. In the specification, the singular forms also include the plural unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this

invention belongs. All patents and publications cited in this specification are incorporated herein by reference.

[0069] Without wishing to be bound by theory, the current invention describes novel methods for producing aptamers with the ability to induce conformational changes in their targets (“agonist SELEX”) and specifically their application, preferably as an adjuvant to be used in conjunction with gp120, as a prophylactic vaccine. Steps central to the agonist SELEX method are illustrated in Figs. 8-10. Specific methods used to generate the HIV vaccine adjuvants are illustrated in Fig. 11.

[0070] Aptamers with potential utility as HIV vaccine adjuvants can be isolated on the basis of their ability to drive conformational changes in gp120 similar to those induced by the natural gp120 receptors/co-receptors (namely CD4 and CCR5/CXCR4). Previously isolated and characterized neutralizing antibodies are known to map to the CD4 and chemokine receptor binding sites. These antibodies can be used both as proxy receptors to partially drive appropriate conformational changes for aptamer selection (Fig. 9) and as probes for detecting appropriate conformational changes induced by aptamers (Fig. 10). As shown schematically in Fig. 8, binding of an agonist to a target promotes conformational changes in the target which change the nature of the target’s interaction (e.g., binding) with a target partner. Typically, the interaction between the target and the target partner promoted by the agonist initiates a signaling pathway within a cell. In a common example, the target is a membrane receptor, the agonist is a peptide or protein ligand or as disclosed herein, an aptamer, and the target partner is an intracellular signaling molecule. In the case of HIV infection, CD4 can be described as an agonist, acting upon the target gp120 to promote its interaction with the target partner CCR5 or CXCR4. An aptamer adjuvant for use as an HIV vaccine would function as an agonist to cause a conformational change in the target (gp120) to expose conserved epitopes and thereby drive association between the target (gp120) and a B-cell receptor.

[0071] As used herein, “agonist” means any molecule (preferably, an aptamer) that upon binding to the target induces an appropriate conformational change in the target. As used herein, “target partner” (or “TP”) means a molecule that specifically interacts (e.g., binds) to the target. As used herein, “target partner analog” (or “TPA”) means a molecule (such as an antibody) that interacts with a target in a manner similar to that of the target partner (e.g., binding at the same or an overlapping site on the target). As used herein, “target partner/analog (or “TP/A”) means either or both a target partner or target partner analog. In the process of “agonist SELEX”, aptamers are isolated on the basis of their ability to (1)

specifically interact with a target which has been driven into an agonist-bound conformation through association with a target partner or an analog thereof, and/or (2) specifically drive association of a target with a target partner or an analog thereof. For *in vitro* selection of gp120 agonists, the target partner receptor (corresponding to a membrane-associated form of a neutralizing antibody expressed on the surface of a B-cell) can be functionally substituted by target partner analogs such as CCR5, CD4, 17b, or b12 (or fragments thereof) – species that are all known to bind to epitopes that drive the binding of neutralizing antibodies. As described below, some agonist SELEX strategies rely upon an agonist competitor. An agonist competitor is a molecule that interacts with the target at the same site as the agonist and which can be used to competitively elute target-bound agonists.

[0072] Aptamers with desired agonist properties can be generated by the broad strategies outlined in Fig. 9 and Fig. 10 and by a number of specific routes, as illustrated in Fig. 11. Initially, all routes start with selection from a random sequence pool for gp120-specific aptamers or ligands (*Step 1*). The gp120-specific aptamer(s) are then used as the starting point for the generation of a biased pool of molecules, predisposed to gp120 binding (*Step 2*). A variety of negative and positive selection pressures can be used to specifically enrich aptamers which trigger conformational changes similar to those generated by receptor/co-receptor-binding (*Steps 3-6*). *Steps 3-6* will individually enrich aptamers within the pool generated in *Step 2* for molecules with agonist properties. Subsequent high-throughput screening of individual clones within the enriched pools can be used to identify optimal aptamers for use as adjuvants (*Step 7*). Alternatively, pools enriched by one step can be used as the starting point for subsequent enrichment *via* another step (*Step 8*). In addition, *Step 1* and/or *Step 2* may be dispensed with altogether such that the ability to bind to gp120 and the ability to cause the appropriate conformational shift in gp120 are selected for simultaneously. By combining multiple selection strategies, aptamers with agonist activity may be most efficiently enriched and ultimately isolated. Detailed methods by which each of the steps in Figure 4 can be carried out are described in the following sections.

[0073] *Step 1: gp120-specific aptamer selection.* In the initial step, aptamers are selected from random sequence pools for specific binding to target (e.g., gp120). In the preferred embodiment, aptamers are derived from the SELEX methodologies previously described. For example, the gp120 specific aptamers can be derived as described below:

(A) A candidate mixture of nucleic acids of differing sequence is prepared. The

candidate mixture generally includes regions of fixed sequences (*i.e.*, each of the members of the candidate mixture contains the same sequences in the same location) and regions of randomized sequences. The fixed sequence regions are selected either: (i) to assist in the amplification steps described below, (ii) to mimic a sequence known to bind to the target, or (iii) to enhance the concentration of a given structural arrangement of the nucleic acids in the candidate mixture. The randomized sequences can be totally randomized (*i.e.*, the probability of finding a base at any position being one in four) or only partially randomized (*e.g.*, the probability of finding a base at any location can be selected at any level between 0 and 100 percent).

(B) The candidate mixture is contacted with the selected target under conditions favorable for binding between the target and members of the candidate mixture. Under these circumstances, the interaction between the target and the nucleic acids of the candidate mixture can be considered as forming nucleic acid-target pairs between the target and those nucleic acids having the strongest affinity for the target.

(C) The nucleic acids with the highest affinity for the target are partitioned from those nucleic acids with lesser affinity to the target. Because only an extremely small number of sequences (and possibly only one molecule of nucleic acid) corresponding to the highest affinity nucleic acids exist in the candidate mixture, it is generally desirable to set the partitioning criteria so that a significant amount of the nucleic acids in the candidate mixture (approximately 5-50%) are retained during partitioning.

(D) Those nucleic acids selected during partitioning as having the relatively higher affinity for the target are then amplified to create a new candidate mixture that is enriched in nucleic acids having a relatively higher affinity for the target. This new candidate mixture is contacted with the selected target under conditions favorable for binding between the target and members of the new candidate mixture to form additional nucleic acid-target pairs.

(E) Steps (C) and (D), partitioning and amplification, respectively, are then repeated until the desired number and types of sequences are obtained.

[0074] By repeating the partitioning and amplifying steps above, the newly formed candidate mixture contains fewer and fewer unique sequences, and the average degree of affinity of the nucleic acids to the target will generally increase. Taken to its extreme, the SELEX process yields a candidate mixture containing one or a small number of unique nucleic acids representing those nucleic acids from the original candidate mixture having the highest affinity to the target molecule.

[0075] The aptamers of the invention can also be prepared through the basic SELEX methodology modified in any manner described herein. The SELEX process can be performed using purified gp120, or discrete domains or fragments (collectively, "fragments") thereof. Alternatively, full-length gp120, or gp120 fragments, can be produced in a suitable expression system. Alternatively, the SELEX process can be performed using as a target a synthetic peptide that includes sequences found in gp120. Determination of the precise number of amino acids needed for the optimal nucleic acid ligand is routine experimentation for skilled artisans. The gp120 fragments can be used in the SELEX process for both negative selections and as the target in lieu of full length gp120 in positive selections. Fragments useful in negative selections are described below. Fragments most likely to be useful in positive selections would be those including the V1 and V2 regions and/or lacking the C1 and/or C5 regions. The identification of other fragments useful in positive selections can be determined by routine experimentation for skilled artisans. Briefly, one would immunize mice or rhesus macaques with various gp120 constructs and screen sera for ability to neutralize HIV infection *in vitro*. gp120 constructs identified which generate the strongest neutralizing response would be chosen. Alternatively, once a gp120-aptamer conjugate has been identified as a useful HIV vaccine, both or either of the aptamer or gp120 could be minimized by deleting portions (*e.g.*, the C1 and/or C5 regions of gp120 or the termini or other nonessential regions of the aptamer), mixing the minimized gp120 and/or aptamer to form conjugates, testing the new conjugate for activity and comparing it to the activity of the full length gp120-aptamer construct.

[0076] In a preferred embodiment, the SELEX process is carried out using fragments of gp120 that are bound to magnetic beads through hydrophobic interactions. A candidate mixture of single stranded RNA molecules is then contacted with the magnetic beads in the wells of a microtiter plate. After incubation for a predetermined time at a selected temperature, the beads are held to the sides of the wells of the plate by a magnetic field, and the wells of the plate are washed to remove unbound candidate nucleic acid ligands. The nucleic acid ligands that bind to gp120 are then released into solution in the wells, then reverse transcribed by reverse transcriptase and amplified using the Polymerase Chain Reaction (PCR). The amplified candidate mixture is then used to begin the next round of the SELEX process.

[0077] In a preferred embodiment, 5-10 cycles of the SELEX process are carried out to isolate a pool of molecules with high affinity and specificity for the target (gp120).

[0078] *Step 2: Generation of a diverse gp120 aptamer-based pool.* To increase the likelihood of isolating not only high affinity ligands but also ligands that induce the appropriate conformational changes in the target, the pool of gp120 aptamers in *Step 1* is “diversified” – *i.e.*, sequence variation is introduced into the selected clones to increase functional diversification. This can be achieved by a combination of several methods including the following:

(A) Individual clones present in the original selection are isolated and characterized. Characterization can include (i) assay for binding affinity, (ii) sequencing, (iii) truncation to define a minimal contiguous domain responsible for binding, (iv) generation of an artificial phylogeny of functional molecules (*e.g.*, *via* random mutagenesis of the aptamer clone, re-selection of the mutagenized pool for binding species (employing the same SELEX process used with the original random pool), sequencing of the re-selected clones, and analysis of the sequenced clones for conserved sequences and structures required for binding). Information obtained by these experiments can be used to direct the chemical synthesis of a new pool of sequences related to the original aptamer clone (some examples are shown in Fig. 12).

(B) One or more of the aptamers isolated in the original selection (*Step 1*) can be used as templates for PCR amplification under mutagenic conditions. Repeated rounds of polymerase-mediated replication lead to incorporation of mutations throughout the aptamer sequence(s).

(C) Random sequence tags can be added to the 5'- and/or 3'-ends of an aptamer or pool of aptamers by either PCR with a random sequence primer or ligation of a random sequence tag (Fig. 12).

[0079] Multiple pool designs can be used in parallel with identical selection protocols to increase the diversity of functional species. In fact, under identical selection conditions, random pools built into a structured ribozyme framework have yielded aptamers in cases where traditional unstructured pools have not. These results suggest that providing some initial stem structure in pools might shift the pools in the nucleic acid thermodynamic/structural landscape into a region more broadly accessible to bind complex or difficult epitopes.

[0080] *Steps 3-6: Selection schemes to isolate gp120 agonists.* As diagrammed in Fig. 11, the pool of gp120 aptamer-based sequences obtained in *Step 2* is subjected to variations on the SELEX process in steps 3-6 to enrich species with or likely to have agonist activity. The output from each *Step* may be assayed for agonist activity or, alternatively, be

provided as input for another step of selection. For example, *Steps 3-4* are designed to isolate gp120 aptamer agonists with CD4-like activity (*i.e.*, prone to induce the conformational changes in gp120 similar to those induced by binding of CD4). Similarly, *Steps 5-6* are designed to isolate gp120 aptamer agonists with chemokine receptor-like activity (*i.e.*, prone to induce conformational changes in gp120 similar to those induced by binding of CCR5/CXCR4). As such, *Steps 3* and *4* can be combined successively to yield one class of agonists while *Steps 5* and *6* can be combined successively to yield another.

[0081] *Step 3: Selection for aptamers that compete for the CD4 binding site of gp120.* Selection for CD4-like agonists by this method follows the general strategy outlined in Fig. 9. The pool of sequences generated in *Step 2* is subjected to repeated rounds of selection as follows:

(1) The pool of gp120 aptamer based sequences is contacted with the immobilized target partner/analog and allowed to bind under conditions that favor specific binding. In the most preferred embodiment, the target partner/analog is the neutralizing antibody 17b, bound to immobilized protein A. Non-binding species are collected and passed forward for subsequent steps.

(2) Target (gp120) or a fragment thereof is immobilized by attachment to a solid support using the immobilized TP/A which, under the experimental conditions is capable of binding the target with high affinity. In the most preferred embodiment, the target is recombinantly expressed gp120/ΔC1ΔC5. The pool of selected sequences is contacted with the immobilized target (gp120) and allowed to bind under conditions that favor specific binding and the species with low affinity for target are removed by stringent washing and discarded.

(3) Excess agonist competitor (*e.g.*, CD4) is combined with the retained pool fraction. CD4 has high affinity for gp120 and will competitively displace aptamers that bind to gp120 *via* sites that overlap with the CD4 binding site. Species specifically eluted by the known agonist are enzymatically amplified as described earlier.

[0082] The above process is repeated until a significant fraction of the input pool is captured and specifically eluted. In the preferred embodiment, this process is repeated 5-10 times.

[0083] As an alternative to the above process, an immobilized complex between target (gp120), agonist competitor (*e.g.*, CD4), and optionally the target partner/analog (*e.g.*, 17b) can be used first in a negative selection step (*i.e.*, the random sequence pool is contacted with said complex and only non-binding species are collected and passed

forward for subsequent steps). Molecules surviving negative selection are subsequently contacted with an immobilized complex containing the target (gp120) and optionally the target partner/analog (17b) but lacking the agonist competitor. Molecules with affinity for the complex are isolated by stringent washing, followed by denaturation.

[0084] The methods described above will preferentially enrich species whose binding site overlaps with that for CD4. While agonists with CD4-like activity would be expected to bind in an overlapping site, several types of parasitic, non-agonist aptamers will additionally be enriched, including, for example, aptamers which only partially overlap with the CD4 binding site and which do not induce the appropriate conformational changes. Previous mutagenesis and crystallographic studies have defined key determinants which direct specific binding between CD4 and gp120 (*e.g.*, Kwong, 1998). These include the V1-V2 extended loop (Thr123-Thr198), Gly366-Asp370, and Met426-Val430. Mutations in these regions are known to disrupt binding and there is evidence that the conformation of these regions is altered as a result of CD4 binding. Aptamer agonists might be expected to rely upon similar interactions to drive target activation and, correspondingly, aptamers that fail to use these interactions may be considered unlikely to drive the appropriate conformational changes. As such, modified targets lacking these sequences/regions and thus agonist binding can be used in negative selection to remove aptamers that bind to the modified targets from the pool.

[0085] In an embodiment of this negative selection strategy, gp120  $\Delta$ C1/ $\Delta$ C5/ $\Delta$ V1-V2 ( $\Delta$ Thr123-Thr198 replaced with the tripeptide Gly-Ala-Gly) is immobilized and contacted with the pool of gp120 aptamer-based sequences under conditions that favor specific binding. Following an incubation period during which specific aptamer-modified target complexes can form, non-bound species are collected and the bound species discarded. Collected species are subsequently passed into a positive selection step for wild-type target (gp120) binding followed by agonist competitive elution. The V1-V2 loop provides approximately half of the contact surface from gp120 in the gp120-CD4 complex and it directly contacts the 17b neutralizing antibody. Aptamers capable of specific gp120 binding in the absence of V1-V2 are unlikely to interact in a way that would alter the conformation of the V1-V2 loop and thus fail to exhibit agonist activity.

[0086] In the same vein, negative selection may be carried out using a gp120  $\Delta$ C1/ $\Delta$ C5/Gly366-Asp370 ->Ala/ $\Delta$ Met426-Val430 mutant. These residues are required for the other half of the gp120-CD4 interaction. Since, however, these residues do not

directly define the binding site for the target partner, it is possible that active agonists will be removed from the selected pool during this step.

[0087] *Step 4: Selection for aptamers that promote target binding to a target partner/analog.* Agonists isolated by this method follow the general strategy outlined in Fig. 10. Pre-binding of CD4 has been shown to increase the affinity of gp120 for antibody 17b by approximately 10-fold (Zhang, 2001) and for the chemokine receptor CCR5 by 100- to 1000-fold. By adjusting target, agonist, and target partner/analog concentrations and other experimental conditions, this property can be exploited to select target binders that increase the affinity of the target for the target partner/analog.

[0088] The target partner/analog (TP/A) is immobilized on a solid support. In the preferred embodiment, the TP/A a sulfotyrosine-rich peptide from CCR5 previously shown to bind specifically to gp120, immobilized *via* biotinylation to a streptavidin-coated plate (Cormier *et al.*, 2000).. Target (gp120) aptamer-based sequences are optionally contacted with the immobilized TP/A and allowed to bind under conditions that favor specific complex formation. Unbound oligonucleotides (also referred to as “species”) are collected and the bound species are discarded.

[0089] The negatively selected sequences from (1) are combined with target and immobilized TP/A under conditions that disfavor efficient binding between target alone and TP/A. Species which are capable of specifically interacting with the target in a manner that increases target affinity for the TP/A will be preferentially retained on the solid support while those that do not will remain in solution. In the preferred embodiment, the concentration of target and TP/A are maintained sufficiently low such that less than 1% of either forms a complex in the absence of an agonist species that would increase their propensity for binding. After an equilibration period in which novel agonist species-target-TP/A complexes are allowed to form, unbound species are removed by stringent washing.

[0090] Optionally, to promote release of target-binding aptamers which form low affinity ternary complexes (aptamer-target-TP/A), excess free target can be provided to competitively displace weakly bound target.

[0091] Specifically retained aptamers can be removed from the immobilized TP/A by denaturation (*e.g.*, by heating) or specifically eluted using, for example, soluble CD4 or 17b Fab (which does not bind protein A).

[0092] *Step 5: Selection for aptamers that compete for gp120 chemokine receptor binding site.* Paralleling efforts directed at the generation of CD4-like agonists, selection

can be used to generate aptamers which bind near the chemokine receptor binding site to induce appropriate presentation of the CD4BS epitopes. Aptamers with this specificity can be generated using the methods described in *Step 3* with replacement of the agonist competitor CD4 by soluble forms of CCR5 or CXCR4 and replacement of the target partner analog 17b with either soluble CD4 or with the neutralizing antibody b12. As an example:

[0093] (1) The pool of gp120 aptamer based sequences is contacted with the immobilized target partner/analog and allowed to bind under conditions that favor specific binding. Non-binding species are collected and passed forward for subsequent steps.

[0094] (2) Target (gp120) or a fragment thereof is immobilized by attachment to a solid support using the immobilized target partner/analog which, under the experimental conditions is capable of binding the target with high affinity. In the most preferred embodiment, the target is recombinantly expressed gp120/ΔC1ΔC5 and the TP/A is monoclonal antibody b12. The pool of selected sequences is contacted with the immobilized target (gp120) and allowed to bind under conditions that favor specific binding. Species with low affinity for target are removed by stringent washing and discarded.

[0095] (3) Excess chemokine receptor binding site competitor (*e.g.*, 17b or detergent solubilized CCR5) is combined with the retained pool fraction. CCR5 and 17b have high affinity for gp120 and will competitively displace aptamers that bind to gp120 *via* sites that overlap with the chemokine receptor binding site. Species specifically eluted by the known agonist are enzymatically amplified as described earlier.

[0096] As with the selection for aptamers that interact *via* the CD4-binding site, selection for chemokine-receptor binding site aptamers will generate non-agonists which interact with a portion of the receptor binding site but do not drive the appropriate conformational changes in the target. These aptamers may be preferentially removed from the selected pool by appropriate negative selection steps involving modified forms of the target in which binding site residues have been deleted or substituted. In the preferred embodiment, a modified form of gp120 lacking the extended V1-V2 variable loop (Thr123-Thr198 → Gly-Ala-Gly) is provided during a negative selection step as described previously for CD4-like agonist selection.

[0097] *Step 6: Selection for aptamers that promote gp120 binding to CD4 or its functional analogs.* Paralleling efforts directed at the generation of agonists which increase binding affinity of gp120 for chemokine receptors and their functional analogs,

selection can be used to generate aptamers with chemokine receptor-like agonist activity by isolating molecules which promote high affinity binding to CD4 or its functional analogs. Aptamers with this specificity can be generated using the methods described in *Step 4* (Fig. 10) with replacement of the agonist CD4 by soluble forms of CCR5 or CXCR4 and replacement of the target partner analog 17b with either soluble CD4 or with the neutralizing antibody b12. As an example:

[0098] (1) The target partner/analog is immobilized on a solid support. In the preferred embodiment, the TP/A is b12 and it is immobilized by non-covalent binding to pre-immobilized protein A using methods for protein A immobilization well-known in the art). Target (gp120) aptamer-based sequences are optionally contacted with the immobilized TP/A and allowed to bind under conditions that favor specific complex formation. Unbound species are collected and the bound species are discarded.

[0099] (2) The negatively selected sequences from (1) are combined with target and immobilized TP/A under conditions that disfavor efficient binding between target alone and TP/A. Species which are capable of specifically interacting with the target in a manner that increases target affinity for the TP/A will be preferentially retained on the solid support while those that do not will remain in solution. In the preferred embodiment, the concentration of target and TP/A are maintained sufficiently low such that less than 1% of either forms a complex in the absence of an agonist species that would increase their propensity for binding. After an equilibration period in which novel agonist species-target-TP/A complexes are allowed to form, unbound species are removed by stringent washing.

[00100] Optionally, to promote release of target-binding aptamers which form low affinity ternary complexes (aptamer-target-TP/A), excess free target can be provided to competitively displace weakly bound target.

[00101] Specifically retained aptamers can be removed from the immobilized TP/A by denaturation (*e.g.*, by heating) or specifically eluted using, for example, non-biotinylated CCR5-derived sulfopeptides with gp120 binding specificity.

[00102] *Step 7: Post-SELEX engineering/optimization of gp120 agonists for use as vaccine adjuvants.* Iterative application of the selection methods described in *Steps 3-6* will yield pools enriched for aptamers with the ability to induce conformational changes in gp120 which will increase its ability to elicit an effective immune response as an antigen. To generate a useful aptamer-based vaccine adjuvant, the following additional steps are

carried out to identify the best starting candidates within the aptamer pool and to improve their production characteristics for use as an adjuvant.

[00103] (1) *Clone screening.* Individual aptamers isolated in the course of *in vitro* selection are cloned and characterized for functional activity. In the initial screen, aptamers may be evaluated on the basis of their ability to promote target partner/analog binding to the target. For example, fluorescently labeled gp120 is combined with a defined amount of CD4-like agonist aptamer clone in an assay plate containing immobilized 17b. Following a binding incubation and stringent washing, retained gp120 can be quantified using a fluorescent plate reader. Aptamers with the strongest agonist activity are expected to most effectively promote gp120 retention in the assay. By testing a range of aptamer concentrations, the highest affinity aptamer agonists may be identified. An advantage of this primary screen is its ability to rapidly evaluate a large number of candidates with minimal effort.

[00104] In a secondary screen, aptamers can be tested in moderate throughput for their ability to induce a neutralizing antibody response. Aptamers can be conjugated to recombinantly expressed gp120 by one of several methods described below and formulated together with a conventional adjuvant, such as Ribi (R-700) or cell wall material (R-730) using methods well known in the art). Aptamer complexes are then injected into mice to provoke an immune response. Specifically, mice are injected with 0.05 ml of vaccine in four subcutaneous sites. Booster immunizations are done at 3-week intervals, and mice bled from the tail 10-28 days after immunizations. Ultimately, larger quantities of serum can be obtained by exsanguinations and serum antibodies against gp120 quantitated by gp120 enzyme-linked immunosorbent assay (ELISA) (Moore *et al.*, 1989). Neutralizing activity of sera is then tested in neutralization assays using human peripheral blood mononuclear (PBMC) target cells (Barnett, S.W. *et al.*, 2001).

(2) *Clone characterization.* Having identified a handful of clones for activity, these clones may be further characterized to improve their production characteristics. Characterization would include the following: (a) *Sequencing.* Plasmid vectors carrying individual cloned aptamers can be sequenced using conventional, well-established, DNA sequencing methods. (b) *Truncation.* End-labeled aptamer is subjected to limited hydrolysis, separated on the basis of target (gp120) binding, and analyzed to determine whether hydrolysis fragments partition as bound or unbound species. Through this process, discrete 5'- and 3'-boundaries can be identified which define a minimal contiguous domain responsible for binding. (c) *Phylogenetic analysis.* An aptamer clone is

subjected to random mutagenesis by either mutagenic PCR or doped re-synthesis of an oligonucleotide template for transcription. The mutagenized pool of sequences is subjected to re-selection using one or more steps described previously (*Steps 3-6*). Functional clones within the re-selected pool are for binding species (employing the same SELEX process used with the original random pool), sequencing of the re-selected clones, and analysis of the sequenced clones for conserved sequences and structures required for binding). (d) *Synthesis*. Minimal aptamers are synthesized using nucleic acid synthesis techniques which are known in the art.

[00105] (3) *Optimization of the aptamers*. Pharmacokinetic properties of aptamers can be optimized by approaches which increase resistance to endonuclease and exonuclease digestion while preserving high affinity gp120 binding. Use of 2'-fluoro-substituted aptamers in starting pools will confer a high degree of nuclease resistance which can be enhanced still further by introduction of 2'-O-methylpurine residues. 2'-O-methyl substitutions may not be tolerated at all purine sites, since the gp120:aptamer complexes may contain contacts between key 2'-OH groups and gp120. Tolerance for 2'-O-methyl substitutions at purine residues of anti-gp120 aptamers will therefore be tested in 2'-O-methyl purine nucleotide interference assays (Greene *et al.*, 1995). Cap structures at the 5'- and 3'- ends of an aptamers are also known to effectively block exonuclease activity (Floege, 1999; Tucker, 1999; Ruckman, 1998; Dougan, 2000). Candidate 2'-fluoropyrimidine and 2'-O-methylpurine-containing aptamers containing 3'-3' thymidine and 3'-biotin cap modifications can be chemically synthesized and tested for gp120 binding and associated binding-induced conformational changes in gp120.

[00106] (4) *Coupling to gp120*. Activity of the aptamer as an effective vaccine adjuvant may require that the aptamer be covalently coupled to gp120. Linkage of aptamers *via* surface carbohydrate moieties of gp120 offers one means to engineer covalently linked aptamer/gp120 complexes. Anti-gp120 aptamers incorporating a variable-length PEG spacer region will be modified by hydrazine treatment and reacted with periodate-oxidized gp120. The resulting covalent aptamer/gp120 complexes will then be characterized with respect to CD4, CCR5 and antibody interaction, and the capacity to generate neutralizing antibodies. Alternatively, the aptamer and gp120 can be photo-crosslinked as previously described.

#### **Administration, Dose and Treatment Regimes**

[00107] The method for preventing HIV infection or reducing the levels of HIV in infected individuals involves exposing a human to an aptamer-gp120 vaccine, actively

inducing antibodies that react with gp120, and preventing/impairing the ability of HIV to infect cells *in vivo*. This method is appropriate for an uninfected subject or an HIV infected subject with a competent immune system. The method induces antibodies, which react with GP120 and neutralize the ability of virus to infect cells. In acutely exposed, previously uninfected individuals, the method will prevent virus multiplication upon exposure to HIV. For already infected individuals, the method will decrease the levels of circulating virus ("viral load"), ameliorating the effects of the disease. The present invention also encompasses treating HIV infection by the administration of gp120 aptamers unconjugated to gp120.

[00108] The terms "treating," "treatment," and the like are used herein to mean obtaining a desired pharmacologic or physiologic effect. The effect can be prophylactic in terms of completely or partially preventing a disorder or sign or symptom thereof, or can be therapeutic in terms of a partial or complete cure for a disorder and/or adverse effect attributable to the disorder. "Treating" as used herein covers any treatment and includes: (a) preventing a disorder from occurring in a subject that can be predisposed to a disorder, but has not yet been diagnosed as having it; (b) inhibiting the disorder, *i.e.*, arresting its development; or (c) relieving or ameliorating the disorder. An "effective amount" or "therapeutically effective amount" is the amount sufficient to obtain the desired physiological effect. Appropriate dosing regimens for the vaccine is generally determined on the basis of controlled clinical trials across patient populations; the effective amount for the vaccine is selected by the physician in each case on the basis of factors normally considered by one skilled in the art to determine appropriate dosages, including the age, sex, and weight of the subject to be treated, the condition being treated, and the severity of the medical condition being treated.

*Administration of aptamer-gp120 Vaccine*

[00109] The aptamer-gp120 vaccine may be formulated and administered through a variety of means, including systemic, localized or topical administration. Preferably, the aptamer-gp120 vaccine is formulated and administered systemically. Techniques for formulation and administration may be found in "Remington: The Science and Practice of Pharmacy, Twentieth Edition," Lippincott Williams & Wilkins, Philadelphia, PA. Suitable routes may include but are not limited to oral, rectal, transmucosal or intestinal administration; parenteral delivery, including intramuscular or subcutaneous injections; or intranasal injections.

[00110] For systemic administration, injection is preferred, including intramuscular (preferred) and subcutaneous. For injection, the vaccines are formulated in aqueous solutions, preferably in physiologically compatible buffers such as Hanks's solution, Ringer's solution, or physiological saline buffer and may include adjuvants (e.g., alums, polymers, copolymers). In addition, the vaccines may be formulated in solid or lyophilized form, then redissolved or suspended immediately prior to use.

[00111] Effective concentrations and frequencies of dosages of the vaccine may be determined through procedures well known to those in the art, which address such parameters as biological half-life, immunologic response, dosing interval, and toxicity. A preferred dosage concentration may range from about 0.1 µg/kg body weight to about 4 µg/kg body weight, with about 0.5 µg/kg body weight being most preferred. Depending on immunogenicity, administration of 2 – 3 doses at monthly intervals, followed by a booster injection at 6 months and subsequently at yearly intervals, may be sufficient to maintain the required circulating concentration of neutralizing antibody. Dose, dosing interval and number of doses will depend upon the patient population (varying by age, weight, underlying diseases, immunologic status etc.).

[00112] The vaccines may be administered to patients alone or in combination with other therapies. Such therapies include the sequential or concurrent administration of small molecule anti HIV inhibitors or antagonists and/or other anti-HIV vaccines that work through different mechanisms (e.g., by generating T-cell-mediated immunity).

### **Pharmaceutical Compositions**

[00113] Pharmaceutical compositions suitable for administration will typically comprise the vaccine and a pharmaceutically acceptable carrier. As used herein, "pharmaceutically acceptable carrier" is intended to include any and all solvents, dispersion media, coatings, antibacterial and antifungal agents, isotonic and absorption delaying agents, and the like, compatible with pharmaceutical administration. Suitable carriers are described in "Remington: The Science and Practice of Pharmacy, Twentieth Edition," Lippincott Williams & Wilkins, Philadelphia, PA. Preferred examples of such carriers or diluents include, but are not limited to, water, saline, Ringer's solutions, dextrose solution and phosphate buffered solutions. Adjuvants such as aluminum phosphate, liposomes and non-aqueous vehicles such as fixed oils may also be used. The use of such media and agents for pharmaceutically active substances is well known in the art. Except insofar as any

conventional media or agent is incompatible with the active compound, use thereof in the compositions is contemplated. Supplementary active compounds can also be incorporated into the compositions.

[00114] A pharmaceutical composition of the invention is formulated to be compatible with its intended route of administration. Examples of routes of administration include parenteral, *e.g.*, intramuscular and subcutaneous, administration. Solutions or suspensions used for parenteral application can include the following components: a sterile diluent such as water for injection, saline solution, fixed oils, polyethylene glycols, glycerine, propylene glycol or other synthetic solvents; antibacterial agents such as benzyl alcohol or methyl parabens; antioxidants such as ascorbic acid or sodium bisulfite; chelating agents such as ethylenediaminetetraacetic acid (EDTA); buffers such as acetates, citrates or phosphates, and agents for the adjustment of tonicity such as sodium chloride or dextrose. The pH can be adjusted with acids or bases, such as hydrochloric acid or sodium hydroxide. Immunogenicity may be enhanced by the inclusion of adjuvants such as alum or other agents commonly known in the field. The parenteral preparation can be enclosed in ampoules, disposable syringes or multiple dose *vials* made of glass or plastic. In all cases, the composition must be sterile and should be fluid to the extent that easy syringeability exists. It must be stable under the conditions of manufacture and storage and if formulated in multi-dose *vials* must be preserved against the contaminating action of microorganisms such as bacteria and fungi.

[00115] Sterile injectable solutions can be prepared by incorporating the active compound in the required amount in an appropriate solvent with one or a combination of ingredients enumerated above, as required, followed by filtered sterilization. Generally, dispersions are prepared by incorporating the active compound into a sterile vehicle that contains a basic dispersion medium and the required other ingredients from those enumerated above. In the case of sterile powders for the preparation of sterile injectable solutions, methods of preparation are vacuum drying, lyophilization and freeze-drying that yields a powder of the active ingredient plus any additional desired ingredient from a previously sterile-filtered solution thereof.

[00116] It is especially advantageous to formulate parenteral compositions in dosage unit form for ease of administration and uniformity of dosage. Dosage unit form as used herein refers to physically discrete units suited as unitary dosages for the subject to be treated; each unit containing a predetermined quantity of active compound calculated to produce the desired therapeutic effect in association with the required pharmaceutical

carrier. The specification for the dosage unit forms of the invention are dictated by and directly dependent on the unique characteristics of the active compound and the particular therapeutic effect to be achieved, and the limitations inherent in the art of compounding such an active compound for the treatment of individuals.

**Methods for Generating Regulated Aptamers**

[00117] A regulated aptamer is an aptamer wherein binding of the aptamer to a second ligand (*e.g.*, the CCR5 receptor) is regulated (*i.e.*, activated or suppressed) by binding of the aptamer to a first ligand or effector (*e.g.*, gp120). An aptamer with these properties can be generated using any of the following selection strategies.

**Method (1): Selection from naïve sequence pools**

[00118] Selection for ligand-regulated aptamers is performed with nucleic acid pools containing 2'- fluoropyrimidines for additional serum stability. For the first pool, a DNA template with the sequence:

5'- GCCTGTTGTGAGCCTCCTGTCGAA- 3' (SEQ ID NO:1), linked by 40 randomized nucleotides -(N<sub>40</sub>)- to 5' -

TTGAGCGTTATTCTTGTCTCCCTATAGTGAGTCGTATTA -3' (SEQ ID NO:2), is synthesized using an ABI EXPEDITE™ DNA synthesizer, and purified by standard methods (N<sub>40</sub> denotes a random sequence of 40 nucleotides built uniquely into each aptamer). Approximately 10<sup>15</sup> DNA molecules with unique sequences from the template pool can be PCR amplified using the primers YW.42.30.A 5'-

TAATACGACTCACTATAAGGGAGACAAGAATAAACGCTCAA-3' (SEQ ID NO:3) and YW.42.30B 5' -GCCTGTTGTGAGCCTCCTGTCGAA-3' (SEQ ID NO:4).

[00119] A second pool, "a semi-structured" pool, uses a DNA template with the following sequence: 5'- GGAGCCTCCTCCGGA- 3' (SEQ ID NO:5) -(N<sub>40</sub>)- 5' - TCCGGTTTCCCGAGCTT-3' (SEQ ID NO:6), is synthesized in the same manner. Approximately 10<sup>15</sup> DNA molecules with unique sequences from the template pool can be PCR amplified using the primers jd6093a 5'-

TAATACGACTCACTATAAGGAGCCTCCTCCGGA -3' (SEQ ID NO:7) and jd6093b 5'- AAGCTCGGGAAACCGGA-3' (SEQ ID NO:8). Amplified pool PCR product is precipitated with ethanol, re-suspended in water and desalting on a Nap-5 column (Pharmacia). Approximately 4 x 10<sup>15</sup> DNA molecules from each of the pool PCR amplifications are transcribed *in vitro* using a mutant Y639F T7 RNA polymerase which

accepts 2'-fluoropyrimidines (Sousa, 1999), 2'-fluoropyrimidine and 2'-OH purine NTPs, to yield  $\sim 3 \times 10^{16}$  RNA molecules with corresponding sequences. Stabilized 2'-fluoropyrimidine pools made up of  $10^{14}$ - $10^{15}$  random sequences in a total volume of approximately 100  $\mu\text{l}$  are contacted with either biotinylated target immobilized in neutravidin coated plates (Pierce) or adherent target-expressing cells immobilized in plates. A typical binding buffer used for the positive and negative selection steps contains 20 mM HEPES, pH 7.4, 150 mM NaCl, 10 mM MgCl<sub>2</sub>, 1 mM EDTA, 1 mM DTT, and 0.1 mg/ml tRNA (4 mM). Following a 10 min. negative incubation step at room temperature, RNAs which bind to the target alone are removed in this negative selection step. The solution containing unbound RNA is then transferred to another identical well containing immobilized target and effector is added to the solution. The concentration of effector added can be adjusted to ultimately enrich molecules which respond to effector at the most appropriate concentration. Initially the effector is provided at saturating concentrations (typically millimolar for small molecule effectors such as glucose and high micromolar concentration for protein effectors) to ensure that molecules with any measure of effector dependence are isolated. In successive rounds of selection, the effector concentration can be reduced to preferentially isolate the most effector-dependent molecules. Following an equilibration period of 1 hour, wells are rinsed with excess binding buffer (typically washing four times with 120  $\mu\text{l}$  of 1x ASB on a robotic plate washer with 30 sec. shakes). 50  $\mu\text{l}$  of RT mix (RT primer, 4  $\mu\text{M}$ ; 5x "Thermo buffer", 1x; DTT, 100 mM; mixed dNTPs, 0.2 mM each; vanadate nucleotide inhibitor 200  $\mu\text{M}$ ; tRNA 10  $\mu\text{g/ml}$ ; 0.5  $\mu\text{l}$  Invitrogen Thermoscript Reverse Transcriptase; brought to 50  $\mu\text{l}$  with water) is added to the selection well and incubated at 65 °C for 30 min with tape over wells to reduce evaporation.

[00120] The RT reaction is diluted 10-fold into a 100  $\mu\text{l}$  PCR reaction (containing 5'-primer, 1  $\mu\text{M}$ ; 3'-primer, 1  $\mu\text{M}$ ; 10x Invitrogen supplied PCR buffer (no Mg), 1x; dNTPs, 0.2 mM each; MgCl<sub>2</sub>, 3 mM; 1  $\mu\text{l}$  Invitrogen Taq; 10  $\mu\text{l}$  incubated RT reaction and brought to 100  $\mu\text{l}$  with water) and thermocycled with the following schedule: 94 °C, 1 min; 62 °C, 1 min; 72 °C 3 min. The PCR reactions are assayed at 10 cycles by agarose gel, and then each successive 5 cycles until defined amplification bands are visible *via* ethidium bromide staining. Completed PCR reactions are purified using a Centri-sep column and diluted 10-fold into a 50  $\mu\text{l}$  transcription reaction (4x TK Transcription buffer, 1x; MgCl<sub>2</sub>, 25 mM; NTPs 5 mM each; NEB T7 RNA polymerase 2  $\mu\text{l}$ ; water to 50  $\mu\text{l}$ ).

The transcription reaction is incubated overnight at 37 °C and the resulting transcription products are purified by denaturing polyacrylamide gel electrophoresis (10% gel).

[00121] The entire selection process is repeated until the fraction of molecules surviving both positive and negative selection increases significantly above the original naïve pool fraction, typically >10% of the input. Typically >10 cycles of selection are required for enrichment. Individual molecules within the enriched pool are isolated and characterized by subcloning the pooled template DNA using the TOPO TA cloning system (Invitrogen). Individual clones are sequenced and unique clones screened for effector dependent binding.

**Method (2): Pre-selection for target binding followed by effector-dependent selection.**

[00122] Selection method (1) can be modified as follows if the probability that molecules with both target and effector binding properties exist in the starting pool is low. Instead of selecting initially for both target binding and effector dependence, *in vitro* selection can be used to isolate molecules with high affinity for the target. Following an optional diversification step (wherein the selected pool of target-binding sequences is partially randomized), effector-dependent selection can be applied. To isolate target specific aptamers, the previously described selection method is applied with the following modifications: (1) target is omitted from the negative selection step, and (2) effector is omitted from the positive selection step. 5-15 rounds of selection will typically yield a pool of target binding species containing 1-1000 unique sequences. Individual clones are screened for the ability to specifically bind to the target.

[00123] A diversified pool of sequences with increased likelihood of effector-dependent target binding activity can be generated by a number of means including the following:

- 1) mutagenic PCR amplification of the enriched target-binding pool of sequences.
- 2) doped resynthesis of individual clone sequence(s) isolated from the target-binding pool, selecting clones that have high affinity and specificity binding. In this case, mutations are introduced at random across the sequence with 10-30% probability at each position or within specified regions of the sequence.
- 3) resynthesis of a functionally important subdomain of individual clone sequence(s) isolated from the target-binding pool, flanked by random-sequence domains. Once individual aptamers are identified from the original pool, the minimal sequence element required for the biochemical activity can be identified through two parallel

approaches: (1) truncation analysis by limited alkaline hydrolysis, and (2) doped reselection (methods are reviewed in Fitzwater & Polisky, 1996). In addition to helping to determine the minimal functional aptamer element, sequence variation introduced *via* doped reselection can provide mutants of the original clone with improved affinity or biochemical activity. The diversified pool is subjected to selection for effector-dependent target binding as described previously.

**Method (3): Pre-selection for effector binding followed by effector-dependent target binding selection.**

[00124] Selection method (1) can be modified as follows if the probability that molecules with both target and effector binding properties exist in the starting pool is low. Instead of selecting initially for both target binding and effector dependence, *in vitro* selection can be used to isolate molecules with high affinity for the effector. Following an optional diversification step (wherein the selected pool of effector-binding sequences is partially randomized), effector-dependent, target-binding selection can be applied as described previously. To isolate effector-specific aptamers, the first selection method is applied with the following modifications: (1) target is omitted from the negative selection step, and (2) target is omitted from the positive selection step and instead effector is immobilized to the capture solid support. In the case of small molecule effectors such as glucose, conventional affinity chromatography using 200 µl agarose bead columns with 1-5 mM immobilized effector is the preferred immobilization format. 5-15 rounds of selection will typically yield a pool of effector binding species containing 1-1000 unique sequences. Individual clones are screened for the ability to specifically bind to the effector.

[00125] A sequence-diversified pool of effector-binding molecules can be generated by one of the following methods:

- 1) mutagenic PCR amplification of the enriched effector-binding pool of sequences,
- 2) doped resynthesis of individual clone sequence(s) isolated from the effector-binding pool, selecting clones that have high affinity and specificity binding. In this case, mutations are introduced at random across the sequence with 10-30% probability at each position or within specified regions of the sequence.
- 3) resynthesis of a functionally important subdomain of individual clone sequence(s) isolated from the effector-binding pool, flanked by random-sequence domains. The

functionally important subdomain of the effector-binding sequences can be defined by truncation of the original clones, following by assays for effector binding.

[00126] The diversified pool is subjected to selection for effector-dependent target binding as described in selection method (1).

**Method (4): Pre-selection for effector binding and target binding motifs, followed by effector-dependent target binding selection.**

[00127] Selection method (1) can be modified as follows if the probability that molecules with both target and effector binding properties exist in the starting pool is low. Instead of selecting initially for both target binding and effector dependence, *in vitro* selection can be used to isolate two separate pools of molecules, one with high affinity for the effector and the other with high affinity for the target. Subdomains within the two pools can be engineered to create a chimeric pool of molecules in which each molecule contains one copy of an effector-binding motif and one copy of a target binding motif. This chimeric pool is then subjected to effector-dependent, target-binding selection as described previously.

[00128] To isolate target specific aptamers, selection method (1) is applied with the following modifications: (1) target is omitted from the negative selection step, and (2) effector is omitted from the positive selection step. To isolate effector-specific aptamers, the selection method (1) is applied with the following modifications: (1) target is omitted from the negative selection step, and (2) target is omitted from the positive selection step and instead effector is immobilized to the capture solid support. In the case of small molecule effectors such as glucose, conventional affinity chromatography using 200 µl agarose bead columns with 1-5 mM immobilized effector is the preferred immobilization format.

[00129] In the preferred embodiment, functional subdomains of high affinity clones from each of the target- and effector-specific pools are used to create the chimeric pool for effector-dependent selection. The functional subdomains can be identified as described previously (selection method (2)). The chimeric pool can be generated by linearly concatenating the functional motifs together with an intervening random sequence domain. Alternatively, the motifs can be combined at the secondary structure level by coupling *via* linking helices as described previously for effector-dependent ribozymes (Soukup, G., and Breaker, R. (1999) "Design of allosteric hammerhead ribozymes activated by ligand-induced structure stabilization." *Structure Fold Des* 7 (7): 783-91).

[00130] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the invention, suitable methods and materials are described above. In the case of conflict, the present Specification, including definitions, will control. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

[00131] All publications and patent documents cited herein are incorporated herein by reference as if each such publication or document was specifically and individually indicated to be incorporated herein by reference. Citation of publications and patent documents is not intended as an admission that any is pertinent prior art, nor does it constitute any admission as to the contents or date of the same. The invention having now been described by way of written description, those of skill in the art will recognize that the invention can be practiced in a variety of embodiments and that the foregoing description and examples below are for purposes of illustration and not limitation of the claims that follow.

## EXAMPLES

### Example 1 Identifying Aptamers with Binding Specificity to gp120

[00132] Figure 4 shows the steps typically required to generate an aptamer for therapeutic purposes. The process can be approximately considered in four phases: (i) and (ii) aptamer identification, (iii) aptamer minimization, and (iv) aptamer optimization for stability.

[00133] Stabilized 2'-fluoro-pyrimidine pools made up of  $10^{14}$ - $10^{15}$  random sequences were contacted with a biotinylated sulfotyrosine-CCR5 peptide (Cormier *et al.*, 2000) immobilized in neutravidin coated 96-well plates (Pierce). Alternatively, adherent CCR5 expressing cells immobilized in 96-well plates can be used. RNAs which bind to the peptide or cells alone were removed in this negative selection step. The RNA solution was then transferred to another identical CCR5 peptide. Alternatively, a cell containing well can be used. At this point gp120 was added to the reactions and they were allowed to equilibrate. Wells were then rinsed with selection buffer and immobilized RNA amplified by reverse transcription, PCR and transcription for another round of activity-based selection. Aptamers selected in this manner both bind to gp120 and induce gp120 binding to CCR5, thus exposing the CCR5 or CD4i epitope. The aptamers generated by activity-

based selection may bind to the CD4 binding site, but this is not absolutely required, as the aptamer may use an alternative mechanism to stabilize gp120 in the CCR5 binding conformation. Since an initial negative selection step was used, aptamers which bind to CCR5 and gp120 simultaneously in a non-allosteric manner should not have been selected. During the post-selection process, pools and clones were screened appropriately to insure that they do not have any CCR5 binding activity in the absence of gp120. A more detailed description of the selection process is provided below.

[00134] **Pool preparation.** Selection for gp120 aptamers was performed with two different nucleic acid pools containing 2'- fluoropyrimidines for additional serum stability. For the first pool, a DNA template with the sequence: 5' - GCCTGTTGTGAGCCTCCTGTCGAA- 3' (SEQ ID NO:1), linked by 40 randomized nucleotides -(N<sub>40</sub>)- to 5' - TTGAGCGTTATTCTGTCTCCCTATAGTGAGTCGTATTA -3' (SEQ ID NO:2), was synthesized using an ABI EXPEDITE™ DNA synthesizer, and purified by standard methods (N<sub>40</sub> denotes a random sequence of 40 nucleotides built uniquely into each aptamer). Approximately 10<sup>15</sup> DNA molecules with unique sequences from the template pool were PCR amplified the primers YW.42.30.A, 5' - TAATACGACTCACTATAAGGGAGACAAGAATAACGCTCAA-3' [SEQ ID No.3] and YW.42.30B, 5' -GCCTGTTGTGAGCCTCCTGTCGAA-3' [SEQ ID No.4]. For the second pool, a "semi-structured" pool, the DNA template sequence 5' - GGAGCCTTCCTCCGGA-3' (SEQ ID NO:5) -(N40)- 5' -TCCGGTTCCCGAGCTT-3' [SEQ ID No.6] was synthesized in the same manner. Approximately 10<sup>15</sup> DNA molecules with unique sequences from the second template pool were PCR amplified using the primers jd6093a 5' - TAATACGACTCACTATAAGGAGCCTTCCTCCGGA -3' [SEQ ID No.7] and jd6093b 5' - AAGCTCGGGAAACCGGA-3'[SEQ ID No. 8]. Amplified pool PCR product was precipitated with ethanol, re-suspended in water and desalted on a Nap-5 column (Pharmacia). Approximately 4 x 10<sup>15</sup> DNA molecules from the pool PCR amplification were transcribed *in vitro* using a mutant Y639F T7 RNA polymerase which accepts 2'-fluoropyrimidines, 2'-fluoropyrimidine and 2'-OH purine NTPs, to yield ~3 x 10<sup>16</sup> RNA molecules with corresponding sequences.

[00135] **Initial selection experiments.** HIV-1 gp120 BaL was the target for use in selections. This strain of gp120 uses CCR5 as its co-receptor and thus is more likely to represent a clinically relevant strain of gp120 for prophylactic vaccine development than a lab-adapted, CXCR4 co-receptor using strain such as HXB2. Purified recombinant gp120

BaL expressed in CHO cells was obtained from Advanced Bioscience Laboratories (Gaithersburg, MD).

[00136] An initial experiment was done using the nitrocellulose filter partitioning method (Tuerk and Gold, 1990; Conrad *et al.*, 1996) to enrich for aptamers that bind to gp120 BaL. Initially,  $2 \times 10^{14}$  unique sequences were equilibrated with 50 – 100 nM gp120 BaL in selection buffer (20 mM K-Hepes pH 7.4, 120 mM NaCl, 1 mM MgCl<sub>2</sub>, 1 mM CaCl<sub>2</sub>, 5 mM KCl) at room temperature for 1 hour. Complexed and free RNA molecules were separated using 0.2 micron nitrocellulose filter disks (Tuerk and Gold, 1990; Conrad *et al.*, 1996). RNA/gp120 BaL complexes were expected to be retained on the nitrocellulose membrane, while unbound RNA would pass through. RNA was eluted from the nitrocellulose membrane by submerging the membrane in 7 M urea, 100 mM sodium acetate, 3 mM EDTA and heating to 90 °C for 5 minutes. The elution process was repeated twice, followed by extraction of the eluate with phenol and ethanol precipitation of the eluted RNA. After annealing to the 3' primer YW.42.30B, the RNA was amplified by reverse transcription at 50 °C for 30 minutes (Thermoscript™ RT, Invitrogen) followed by PCR under standard conditions (Taq polymerase, Invitrogen) using the primers YW.42.30B and YW.42.30A, yielding the corresponding DNA templates for the second round of selection. Subsequent rounds of selection were conducted using a similar procedure, except that the pooled RNA was passed through a nitrocellulose filter prior to incubation with gp120 to remove molecules that bound to nitrocellulose. After 8 rounds of selection, gp120 BaL specific binding was detectable when compared with naïve pool in a standard nitrocellulose filter binding assay (Figure 5) using 5'-<sup>32</sup>P labeled RNA pool. While the extent of binding was low, the goal of this initial step was not to drive selection to generate the highest affinity aptamers, but merely to demonstrate that a naïve pool could be enriched for gp120 BaL binding.

[00137] **Activity-based selection for anti-gp120 aptamers that promote gp120 binding to CCR5.** Once a naïve pool for gp120 BaL binding was successfully enriched, an agonist (or activity) based selection strategy (agonist SELEX) was performed. Selection was initiated by equilibration of  $4 \times 10^{14}$  -  $4 \times 10^{15}$  naïve RNA pool molecules with a biotinylated sulfotyrosine-CCR5 peptide of the sequence: NH<sub>2</sub>-DYQVSSPI(SO<sub>3</sub>)YDIN(SO<sub>3</sub>)YYTSEGAGK-biotin-NH<sub>2</sub> (SEQ ID NO:226) (Cormier *et al.*, 2000) (synthesized and purified by SynPep (Dublin, CA)) immobilized in a

Neutravidin coated 96 well plate (Pierce) in a 100 µl binding reaction in selection buffer, to remove RNA molecules capable of binding to the CCR5 peptide only. After equilibration with peptide alone, the RNA solution was transferred to a fresh well containing immobilized CCR5 peptide. To this second well, gp120 BaL was added to a final concentration of from 50 – 100 nM and the RNA/gp120 solution was allowed to equilibrate with immobilized peptide for 1 hour at room temp. The solution was then removed from the well and discarded. The well was then washed 4-8 times with 200 µl of selection buffer and the washes were also discarded. Peptide bound gp120/RNA complexes were simultaneously eluted and reverse transcribed directly from the well at 65 °C for 30 minutes (Thermoscript™ RT, Invitrogen) followed by PCR under standard conditions (Taq polymerase, Invitrogen) using the primers YW.42.30B and YW.42.30A, and transcription of amplified DNA for the subsequent round of selection.

[00138] After 13 rounds of activity-based selection, the pool was tested for the ability to bind to gp120 BaL. Successfully selected RNA molecules must have the ability to bind to gp120. As shown (Figure 6), the 5'-<sup>32</sup>P labeled RNA pool that only went through activity-based selection now binds to gp120 BaL with moderate affinity,  $K_D \sim 200$  nM in a nitrocellulose filter binding assay, while the original unselected naïve pool does not bind at all. As additional controls, ELISA assays have shown that gp120 BaL alone did not bind to neutravidin coated plates in either the presence or absence of the CCR5-peptide, and that the activity selected pool did not bind to neutravidin or to CCR5-peptide/neutravidin complexes in the filter binding assay. These results suggest that components of the activity selected pool do in fact have the ability to mimic the action of CD4 on gp120.

[00139] In order to further test the ability of the activity selected pool to mimic the action of CD4 on gp120, a plate binding experiment was performed using 5'-<sup>32</sup>P labeled activity selected pool (or naïve pool as a negative control) under standard selection conditions (described above). This experiment measured the counts remaining in neutravidin coated plates as a function of the presence of CCR5 peptide, gp120 BaL, both or neither component. These results (Figure 7) further suggest that the ability of labeled RNA to bind in a well is dependent on activity selection, CCR5 peptide and gp120 BaL, and thus that aptamers able to mimic the action of CD4 upon gp120 BaL have been enriched in the pool of molecules. In other tests using this same assay, inconsistent results

were obtained likely because of the low sensitivity of the assay. To clarify the results, additional assays such as those described in Examples 4 to 7 are performed.

[00140] Clones from the activity-based selections were screened. Two dominant clones from the N40 pool activity-only based selections have gp120 BaL specific binding. They are:

>SEQ ID No: 9: PLATE#713.E09.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTCGACAGGGGCTACAACAGGC

>SEQ ID No: 10: PLATE#713.D09.M13F  
GGGAGACAAGAATAAACGCTCAATAGGGTGACCGACAATAATGGGAGTCA  
AACTGTTGTGTTCGACAGGAGGCTACAACAGGC

[00141] The sequences of SEQ ID No. 11 through SEQ ID No. 28 were generated from R8 of the anti-gp120 BaL filter binding selection with N40 pool (no activity based selection yet).

>SEQ ID No. 11 : gp1208DA\_82-D4  
GGGAGACAAGAATAAACGCTCAACTGTCGTATTATTTTAGCGGTCTCAA  
CTAATTGTGGCTTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 12: gp1208DA\_82-C5  
GGGAGACAAGAATAAACGCTCAACTGTCGTATTATTTTAGCGGTCTCAA  
CTAGNTGTGGCTTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 13: gp1208DA\_82-E2  
GGGAGACAAGAATAACCCCTAACCTCGCGTTGTCAAAGTATTTTG  
AAGGAATTGTGACTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 14: gp1208DA\_82-A3  
GGGAGACAAGAATNANCNCTAACCTCGCGTTGTCAAAGTATTTTG  
AAGGAATTGTGACTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 15: gp1208DA\_82-F4  
GGGAGACAAGAATAAACGCTCAACTGTCGTATTATTTTAGCGGTCTCAA  
CTAANNGTNGCTTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 16: gp1208DA\_82-C4  
GGGAGACAAGAATNAACGCTAACCTCGCGTTGTCAAAGTATTTTG  
AAGGAATTGTGACTTCNACAGGAGGCTACAACAGGN

>SEQ ID NO. 17: gp1208DA\_82-C1  
GGGAGACAAGAATNNACCCTAACCTGTCGNATTATTTCAGCGGNCTCAA  
CTAATTGTGGCTTTCGACAGGAGGCTACAACAGGN

>SEQ ID NO. 18: gp1208DA\_82-C3

GGGAGACAAGAATAAACGCTCAACCTCGCGTTTGTCAAAGTATTTTG  
AAGGNANNNTGACTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 19: gp1208DA\_82-B5  
GGGAGACAAGAATAAACGCTCAACTGTCGTATTATTTAGCGGTCTCAA  
CTAANNNGTNACTTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 20: gp1208DA\_82-A1  
GGGAGACAAGAATAAACGCTCAACCTCGCGNTNGTCAAAGTATTNNG  
ANGGAAAAGNGANTNGACAGGAGGCTCNCAACAGGC

>SEQ ID NO. 21: gp1208DA\_82-E1  
GGGAGACAAGAATAAACGCTCAACGTACTGGTTATTCCCTGGTTAGCGTAA  
AGTAGTAAGTGAGTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 22: gp1208DA\_82-C2  
GGGAGACAAGAATAAACGCTCAAGTAAGATAGCAGGTTATAGAGGCAGAA  
CANAATGTGAGTTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 23: gp1208DA\_82-G4  
GGGAGACAAGAATAAACGCTCAACTGAGTGAGGAAATNGGGAGCATCTT  
ACGGGGANAATTGTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 24: gp1208DA\_82-H5  
GGGAGACAAGAATAAACGCTCAATAAGAGGTTAAAGTGAGACAGNCTAAT  
TAGATGGGAANTAGTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 25: gp1208DA\_82-A5  
GGGAGACAAGAATAAACGCTCAATGGGAGGTGAGCGTAGATGGGGATATT  
ATGCGTTGCGTGATTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 26: gp1208DA\_82-D1  
GGGAGACAAGAATNNACCCTCAACTTATCTGAGGAAATACGGATCTTATT  
GCATTTAGCGACGTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 27: gp1208DA\_82-E3  
GGGAGACAAGAATNANCCTCAAGATTGACACACAGTAAAAAATAGTAC  
AGTAAGTGAGTGCGCTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 28: gp1208DA\_82-A4  
GGGAGACAAGAATAANCCTCAAGTTCNANTNACCTGNNNTANTCNT  
NCATGTGCNATTTCGACAGGAGGCTACAACAGGC

**[00142]** The sequences of SEQ ID No. 29 through SEQ ID No. 36 were generated from R8 of the anti-gp120 BaL filter binding selection with SS pool (no activity based selection yet).

>SEQ ID NO. 29: gp1208DE\_82-A8  
GGANCCTTCCTCCGGAGGTNTTNATATTNCATTACAAGGGNAAANNTCT

TTTGGNTCCGGTTCCCGANCTT

>SEQ ID NO. 30: gp1208DE\_82-E8  
GGAGCCTTCCTCCGGACTTACAGCACAAANTTAAATTACGGGNAANCTCG  
TCCCCGTCCGGTTCCCGAGCTT

>SEQ ID NO. 31: gp1208DE\_82-A7  
GGAGCCTTCCTCNGCNCTGTGTGTTAAAATTTTATTGCGCTTTTG  
TTTCTCGTCCGGTTCCCGAGCTA

>SEQ ID NO. 32: gp1208DE\_82-D7  
GGAGCCTTCCTCCGGATCGTGTACATTCTCCAATGATTATACTGTTAT  
TTACTGTCCGGTTCCCGAGCTT

>SEQ ID NO. 33: gp1208DE\_82-F7  
AGCCTTCCTCCGGAAATTATTANCNNTCTATTAGACGGNNAANGCGTT  
TAGGTCCGGTTCCCGAGCTT

>SEQ ID NO. 34: gp1208DE\_82-C8  
GGAGCCTTCCTCCGGACGGGATAAATAACATAGTANGNNAACAGGG  
TGTTGGTCCGGTTCCCGAGCTT

>SEQ ID NO. 35: gp1208DE\_82-F8  
GGAGCCTTCCTCCGGAAATCGGCATANTNNACAGTCATANGNNANNTGTT  
CTCCCACCGGTTCCCGAGCTT

>SEQ ID NO. 36: gp1208DE\_82-C7  
GGAGCCTTCCTCCGGACCCTATTCTGTATCGGCTTATATATATCCGAT  
TGCCTCGTCCGGTTCCCGAGCTT

[00143] The sequences of SEQ ID No. 37 through SEQ ID No. 67 were generated from R8 of the anti-gp120 BaL filter binding selection with N40 pool and then through 10 rounds of the activity based selection with the CCR5 peptide included.

>SEQ ID NO. 37: PLATE#910.C10.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTTT-ATTCGGTTGAT  
GGGCACGTGTTTTT-ATTCGACAGGGAGGCTCACACAGGC-

>SEQ ID NO. 38: PLATE#910.B11.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTTT-ATTCGGTTGAT  
GGGCACGTGTTTTT-ATTCGACAGGGAGGCTCACACAGGC-

>SEQ ID NO. 39: PLATE#910.C12.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTCTT-ATTCGGTTGAT  
GGGCACGTGTTTTT-ATTCGACAGGGAGGCTCACACAGGC-

>SEQ ID NO. 40: PLATE#910.H12.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTTT-ATTCGGTTGAT

GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 41: PLATE#910.H11.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTT-ATTCGGTTGAT  
GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 42: PLATE#910.F12.M13F  
GGGAGACAAGAATAAACGCTCAAGCCTGTGGAGTTTT-ATTCGGTTGAT  
GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 43: PLATE#910.F11.M13F  
GGGAGACAAGAATAAACGCTCAAGCCTGTAGAGTTTT-ATTCGGTTGAT  
GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 44: PLATE#910.A10.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGCTTT-ATTCGGTTGAT  
GAGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 45: PLATE#910.D10.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGCTTT-ATTCGGTTGAT  
GAGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 46: PLATE#910.G09.M13F  
GGGAGACAAGAATAAACGCTCAAGCCTGTAGAGCTTT-ATTCGGTTGAT  
GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 47: PLATE#910.D09.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTTATTCGGTTGAT  
GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 48: PLATE#910.F10.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTTATTCGGTTGAT  
GGGCACTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 49: PLATE#910.C11.M13F  
GGGAGACAAGAATAAACGCTCAAGCCTGTAGAGTTTT-ATTCGGTTGAT  
GGCGCTGTTTTT-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 50: PLATE#910.D11.M13F  
GGGAGACAAGAATAAACGCTCAATAGGGTGACCGAC---AATAATGGGAG  
TCAAACGTGTTG-TGTGTTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 51: PLATE#910.E11.M13F  
GGGAGACAAGAATAAACGCTCAATAGGGTGACCGAC---AATAATGGGAG  
TCAAACGTGTTG-TGTGTTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 52: PLATE#910.E12.M13F  
GGGAGACAAGAATAAACGCTCAANAGGGTGACCGAC---AATAATGGGAG  
TCAAACGTGTTG-TGTGTTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 53: PLATE#910.B12.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGAC---AATTATGGGAG  
TCAGCTTGTG-AGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 54: PLATE#910.B10.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGAC---AATTATGGGAG  
TCAGCTTGTG-AGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 55: PLATE#910.G10.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGAC---AATTATGGGAG  
TCAGCTTGTG-AGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 56: PLATE#910.A11.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGAC---AATTATGGGAG  
TCAGCTTGTG-AGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 57: PLATE#910.G11.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGAC---AATTATGGGAG  
TCAGCTTGTG-AGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 58: PLATE#910.C09.M13F  
GGGAGACAAGAATAAACGCTCAATAGGGTGACCGAC---AATNATGGGAG  
TCANNCNGTTGATGTGTTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 59: PLATE#910.E10.M13F  
GGGAGACAAGAATAAACGCTCAATGTTGAAGTGTGTT---AGTAAGTGAAG  
CCGCTGTTTAGTTGTTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 60: PLATE#910.E09.M13F  
GGGAGACAAGAATAAACGCTCAATAGGGTGACCGAC---AAGATGGGAGT  
CCAATTGTTG--TGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 61: PLATE#910.D12.M13F  
GGGAGACAAGAATAAACGCTCAAACA-GTGTAGCTCGTGTGATTG-CTAGG  
GTGTCCGACAGAAC-ATTCGACAGGAGGCTCACAAACAGGC

>SEQ ID NO. 62: PLATE#910.G12.M13F  
GGGAGACAAGAATAAACGCTCAAGT--GAGTCTTCCATCGATTTCCTGG  
GTGTCCGACAGAGC-ATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 63: PLATE#910.H09.M13F  
GGGAGACAAGAATAAACGCTCAAAGAGGCCGTGATCG---TTATCGAATGG  
GTGTCCGACGATTGTTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 64: PLATE#910.A09.M13F  
GGGAGACAAGAATAAACGCTAACATAATGTGAA-----  
-----GCTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 65: PLATE#910.B09.M13F  
GGGAGACAAGAATAAACGCTAACATAATGTGAA-----

-----GCTTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 66: PLATE#910.A12.M13F  
GGGAGACAAGAATAAACGCTCAACATAATGTGAA-----  
-----GCTTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 67: PLATE#910.F09.M13F  
GGGAGACAAGAATAAACGCTCAACATAATGTGAA-----  
-----GCTTCGACAGGAGGCTCACAACAGGC-

[00144] The sequences of SEQ ID No. 68 through SEQ ID No. 115 were generated from R10 of activity selection only with the N40 pool (no pre-enrichment for BaL binders).

>SEQ ID NO. 68: PLATE#710.C05.M13F  
-GGGAGACAAGAATAAACGCTCAA-TGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 69: PLATE#710.C06.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 70: PLATE#710.E04.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 71: PLATE#710.E05.M13F  
-AGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 72: PLATE#710.F05.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 73: PLATE#710.A06.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 74: PLATE#710.B01.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 75: PLATE#710.H05.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 76: PLATE#710.H01.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAACAGGC-

>SEQ ID NO. 77: PLATE#710.B04.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 78: PLATE#710.B05.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 79: PLATE#710.F03.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 80: PLATE#710.H06.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 81: PLATE#710.F06.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 82: PLATE#710.G01.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 83: PLATE#710.F04.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAG-ACTGTTGTGTTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 84: PLATE#710.H03.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAG-ACTGTTGTGTTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 85: PLATE#710.G06.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAG-ACTGTTGTGTTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 86: PLATE#710.D05.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAG-ACTGTTGTGTTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 87: PLATE#710.A03.M13F  
-GGGAGACAAGAATAAACGCTCAAATTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 88: PLATE#710.B03.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGGGTGACCGACA-ATAATGGGAG  
TCAG-ACTGTTGTGTTCGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 89: PLATE#710.A05.M13F

-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 90: PLATE#710.E01.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 91: PLATE#710.D01.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 92: PLATE#710.C02.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 93: PLATE#710.B06.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 94: PLATE#710.D02.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 95: PLATE#710.F01.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACTGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 96: PLATE#710.E06.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAA-GCTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 97: PLATE#710.B02.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCAA-GCTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 98: PLATE#710.G02.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTCGTTGAGAGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 99: PLATE#710.H04.M13F  
-GGGAGACAAGA ATAAACGCTCAANAGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 100: PLATE#710.H02.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-TTTATGGGAG  
TCAG-CTTGTGAGAGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 101: PLATE#710.D03.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAG-CTTGT-GAGAGTTCGACAGGGAGGCTCACAAACAGGC-

>SEQ ID NO. 102: PLATE#710.E03.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGGCCGACA-ATTATGGGAG  
TCAG-CTTGTGAGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 103: PLATE#710.F02.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATAATGGGAG  
TCAA-ACTGTTGTGNGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 104: PLATE#710.E02.M13F  
-GGGAGACAAGAATAAACGCTCAA-TTGGGTGACCGACA-ATTATGGGAG  
TCAAACCTGTTGAGAGTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 105: PLATE#710.G05.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATAATGGGAG  
TCCA-ATTGTTGTGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 106: PLATE#710.G04.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATAATGGGAG  
TCCA-ATTGTTGTGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 107: PLATE#710.A04.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGACA-ATAATGGGAG  
TCCA-ATTGTTGTGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 108: PLATE#710.C01.M13F  
-GGGAGACAAGAATAAACGCTCAATAGGG-TGACCGATA-ATAATGGGAG  
TCAA-ACTGTTGTGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 109: PLATE#710.D06.M13F  
AGGGAGACAAGA-TAAACGCTCAATAGGG-TGACCGACA-ATAGTGGGAG  
TCAA-ACTGTTGTGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 110: PLATE#710.A02.M13F  
-GGGAGACAAGAATAAACGCTCAACGGGG-TGACCGACA-ATAATGGGAG  
TCCA-ATTGTTGTGTTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 111: PLATE#710.C03.M13F  
-GGGAGACAAGAATAAACGCTCAATGGGG-TGACCGACA-ATTATGGGAG  
TCTA-AATGTTGTGATTCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 112: PLATE#710.A01.M13F  
-GGGAGACAAGAATAAACGCTCAATTGGG-TGACCGACA-TTTATGGGAG  
TCCA-ATCGTTGTGAATCGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 113: PLATE#710.C04.M13F  
-GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTT-ATTCGGTTGA  
TGGGCACTTTTATTGACAGGAGGCTCACAAACAGGC-

>SEQ ID NO. 114: PLATE#710.D04.M13F

-GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTT-ATTCGGTTGA  
TGGGCACTGTTTTATTGACAGGAGGCTACAACAGGC-

>SEQ ID NO. 115: PLATE#710.G03.M13F  
-GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTTATTGCGGTGA  
TGGGCACTGTTTTATTGACAGGAGGCTACA-CAGGCA

[00145] The sequences of SEQ ID No. 116 through SEQ ID No. 161 were generated from R13 of activity selection only with the N40 pool (no pre-enrichment for BaL binders).

>SEQ ID NO. 116: PLATE#713.E09.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 117: PLATE#713.H07.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 118: PLATE#713.A09.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 119: PLATE#713.A10.M13F  
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GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 121: PLATE#713.B10.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 122: PLATE#713.D12.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 123: PLATE#713.B12.M13F  
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GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 124: PLATE#713.B09.M13F  
GGGAGACAAGAATAAACGCTCAATTGGGTGACCGACAATTATGGGAGTCA  
GCTTGTGAGAGTTGACAGGGGCTACAACAGGC

>SEQ ID NO. 125: PLATE#713.G12.M13F  
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>SEQ ID NO. 126: PLATE#713.F12.M13F  
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>SEQ ID NO. 127: PLATE#713.G09.M13F  
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>SEQ ID NO. 128: PLATE#713.E08.M13F  
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GCTTGTGAGAGTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 130: PLATE#713.G10.M13F  
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>SEQ ID NO. 132: PLATE#713.F08.M13F  
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>SEQ ID NO. 133: PLATE#713.C10.M13F  
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GACTGTTGTGTTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 134: PLATE#713.B07.M13F  
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GCTTGTGAGAGTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 135: PLATE#713.C11.M13F  
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>SEQ ID NO. 142: PLATE#713.A12.M13F  
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>SEQ ID NO. 144: PLATE#713.E10.M13F  
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AGCTGTTGTGTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 145: PLATE#713.B08.M13F  
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AGCTGTTGTGTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 146: PLATE#713.H12.M13F  
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>SEQ ID NO. 147: PLATE#713.E12.M13F  
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GACTGTTGTGTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 148: PLATE#713.C12.M13F  
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>SEQ ID NO. 149: PLATE#713.E07.M13F  
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AATTGTTGTGTCGACAGGAGGCTACAACAGGC

>SEQ ID NO. 150: PLATE#713.C08.M13F  
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AACTGTTGTGTTCGACAGGAGGGCTACAACAGGC

>SEQ ID NO. 151: PLATE#713.H09.M13F  
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>SEQ ID NO. 152: PLATE#713.A07.M13F  
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AAATGTTGTGATTTCGACAGGGGCTACAACAGGC

>SEQ ID NO. 153: PLATE#713.E11.M13F  
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AGCTGTTGTGTTCGACAGGAGGGCTACAACAGGC

>SEQ ID NO. 154: PLATE#713.G08.M13F  
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AACGTTGTGATTTCGACAGGAGGGCTACAACAGGC

>SEQ ID NO. 155: PLATE#713.A11.M13F  
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>SEQ ID NO. 156: PLATE#713.D07.M13F  
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>SEQ ID NO. 157: PLATE#713.C09.M13F  
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>SEQ ID NO. 158: PLATE#713.F09.M13F  
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GGGCACTGTTTTATTGACAGGAGGGCTACAACAGGC

>SEQ ID NO. 159: PLATE#713.D08.M13F  
GGGAGACAAGAATAAACGCTCAATCCTGTAGAGTTTATTGGTTGAT  
GGGCACTGTTTTATTGACAGGAGGGCTACAACAGGC

>SEQ ID NO. 160: PLATE#713.C07.M13F  
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GGGCACTGTTTTATTGACAGGAGGGCTACAACAGGC

>SEQ ID NO. 161: PLATE#713.B11.M13F  
GGGAGACAAGAATAAACGCTCAACCTGTCATGGGACGTTAACTACT  
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[00146] The sequences of SEQ ID NO. 162 through SEQ ID No. 225 were generated from either R10 or R13 of activity selection only with the SS pool (no pre-enrichment for

BaL binders) (plate 810 sequences went through 10 rounds and plate 813 sequences went through 13 rounds).

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CTT—ATTGTCCGGTTCCCGAGCTT

>SEQ ID NO. 164: PLATE#813.C06.M13F  
GGAGCCTCCTCCCGAAGTCAAGAGTAA--CACAGGAAATGCGTACTCTT  
CTT—ATTGTCCGGTTCCCGAGCTT

>SEQ ID NO. 165: PLATE#813.C07.M13F  
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CTT—ATTGTCCGGTTCCCGAGCTT

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GGAGCCTCCTCCCGAAGTCAAGAGTAA--CACAGGAAATGCGTACTCTT  
CTT—ATTGTCCGGTTCCCGAGCTT

>SEQ ID NO. 167: PLATE#810.C02.M13F  
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CTT—ATTGTCCGGTTCCCGAGCTT

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CTT—ATTGTCCGGTTCCCGAGCTT

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CTT—ATTGTCCGGTTCCCGAGCTT

>SEQ ID NO. 174: PLATE#813.H06.M13F  
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>SEQ ID NO. 175: PLATE#810.H03.M13F  
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>SEQ ID NO. 177: PLATE#810.E01.M13F  
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>SEQ ID NO. 178: PLATE#813.F08.M13F  
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>SEQ ID NO. 189: PLATE#810.C01.M13F  
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TTGCGTCGCCTCCGGTTCCGAGCTT

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TTGCGTCGCCTCCGGTTCCGAGCTT

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>SEQ ID NO. 197: PLATE#813.F05.M13F  
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TTGCGTCGCCTCCGGTTCCCGAGCTT

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>SEQ ID NO. 206: PLATE#810.A04.M13F  
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>SEQ ID NO. 209: PLATE#813.A07.M13F  
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ACT-TTTGTGTCCGGTTCCCGAGCTT

>SEQ ID NO. 210: PLATE#810.G02.M13F  
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TTNCGTNCCTCCGGTTCCCGAGCTT

>SEQ ID NO. 211: PLATE#810.A01.M13F  
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AGTGTGCATATCCGGTTCCCGAGCTT

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CTTCGGGGTCCGGTTCCCGAGCTT

>SEQ ID NO. 213: PLATE#810.D01.M13F  
GGAGCCTCCTCCGGATGCGA-AAGTA---TGATGGTCTTACTTTGAA  
CATCCTGTGGTCCGGTTCCCGAGCTA

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CTTGGTGGCGTCCGGTTCCCGAGCTT

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TACACT-TGGTCCGGTTCCCGAGCTT

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TTG-AGTTGGTCCGGTTCCCGAGCTT

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TTG-AGATGGTCCGGTTCCCGAGCTT

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TCT-TTTGGGTCCGGTTCCCGAGCTT

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TGT-TCGTGGTCCGGTTCCCGAGCTT

>SEQ ID NO. 223: PLATE#810.F04.M13F  
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TCTGTTGG—TCCGGTTCCCGAGCTT

>SEQ ID NO. 224: PLATE#810.H02.M13F  
GGAGCCTTCCTCCGGAAA-TCGACATAGTCCGCTAATTTTGCTCGTTAG  
TCAGCTG---TCCGGTTCCCGAGCTT

>SEQ ID NO. 225: PLATE#813.F07.M13F  
GGAGCCTTCCTCCGGAAA-CCCGCATCATAGGCGATTGGATAGCA---A  
TCCACCTACATCCGGTTCCCGAGCTT

EXAMPLE 2      Aptamer Minimization

[00147] SELEX typically yields RNA molecules 70 to 90 nucleotides long. Minimizing aptamer length facilitates chemical synthesis of aptamer candidates and can increase the affinity of the aptamer-ligand complex by eliminating alternative, non-binding structures. Once individual aptamers are identified from the original pool, the minimal sequence element required for high affinity binding can be identified through two parallel approaches: (1) truncation analysis by limited alkaline hydrolysis, and (2) doped reselection (methods are reviewed in Fitzwater & Polisky, 1996).

EXAMPLE 3      Aptamer Optimization for Nuclease Resistance

[00148] Nucleic acids are degraded in serum by a combination of endonucleases and 5'→3' and 3'→5' exonucleases. Appropriate chemical modifications, as otherwise disclosed herein, block each activity (Pieken *et al.*, 1991; Cummins *et al.*, 1995; Jellinek *et al.*, 1995; Dougan *et al.*, 2000). Briefly, incorporation of 2'-fluoropyrimidines during selection in transcription reactions, and post selection addition of 2'-O-methyl purines protect aptamers from endonuclease degradation, while modification of termini with a 3'-3' thymidine cap can provide significant resistance to exonucleases.

EXAMPLE 4      Clonal Analysis and Aptamer Activity Assays

[00149] When selection has reached the point where further rounds do not increase the fraction of pooled RNA bound to gp120, or to other complexes detailed above, the pooled template DNA are cloned using the TOPO TA cloning system (Invitrogen). Individual clones are sequenced. Unique clones are screened for the desired properties using the techniques outlined below.

[00150] Selected aptamer clones are evaluated on the basis of their ability to bind to gp120. Simple binding is required for aptamers to be CD4 mimics and thus can be used to rapidly triage the library of selected aptamer clones. Individual clones which demonstrate gp120 binding are carried forward for further screening on the basis of the ability to mimic the biological action of CD4 on gp120. Sensitive three-component optical biosensor binding assays are configured to detect CD4 or aptamer inducible changes in binding affinities of gp120 for biotinylated CCR5 peptide (Cormier *et al.*, 2000), on a Biacore 3000 surface plasmon detection system. In addition, gp120 dependent binding of <sup>32</sup>P-labeled aptamer clones on CCR5 expressing cells are screened in filter binding experiments functionally analogous to those used to quantitate the effects of sCD4 upon gp120 binding to co-receptors (Doranz *et al.*, 1999) as well as for the ability of binding to be specifically blocked by the CCR5 specific monoclonal antibody 3A9 (Wu *et al.*, 1997) and the gp120 CD4i epitope specific antibody 17b (Kwong *et al.*, 1998). Cells expressing CCR5 can be obtained, *e.g.*, from Merck Research Laboratories (West Point, PA), soluble CD4 has been purchased from US Biologics (Swampscott, MA) and antibodies 3A9 and 17b are freely available from the NIH AIDS Research and Reference Reagent Program.

EXAMPLE 5Covalent Coupling of Aptamers to gp120

[00151] Activity of the aptamers in an effective vaccine are enhanced when the aptamers are covalently coupled to gp120. Anti-gp120 aptamers are synthesized with polyethylene glycol (PEG) spacers at their 5'-termini to yield aptamers with from ~20-200 Å (Angstrom) spacers ending in a primary amine moiety. The length and “water-like” properties of the spacer allow the aptamer to bind to gp120 in a manner identical to that observed in an uncoupled 2-piece system. A series of single cysteine mutations in the N and C termini and non-neutralizing face of gp120 are generated by standard mutagenesis techniques. Amine terminated aptamers are then covalently attached to free thiols on gp120 using a hetero-bifunctional crosslinker available from Pierce (Sulfo-LC-SPDP, sulfosuccinimidyl 6-[3'-(2-pyridylidithio)-propionamido] hexanoate). Aptamer/gp120 conjugates are then screened for the ability to bind to CCR5 peptide or to CCR5 expressing cells as described above. By testing multiple gp120 BaL mutants and aptamer spacer lengths the optimal configuration for biochemical activity is identified.

EXAMPLE 6Generation of antibodies against aptamer/gp120 immunogens

[00152] Aptamers demonstrating activity in *in vitro* functional assays are covalently coupled to gp120 and complexes assayed for the ability to induce neutralizing antibody responses. Immunogens are formulated with the saponin based QS21 adjuvant at final concentrations of 50-100 µg/ml and 100 µg/ml respectively (Evans *et al.*, 2001 and McGaughey *et al.*, 2003). At least six sets of immunization experiments can be performed in parallel. Guinea pigs are immunized with either: i.) optimized aptamer/gp120 conjugate, ii.) a scrambled sequence (nonfunctional) aptamer/gp120 conjugate, iii.) aptamer/gp120 complex without covalent conjugation, iv.) scrambled sequence aptamer/gp120 complex without covalent conjugation, v.) gp120 only, or vi.) adjuvant only. Thus, the effects of the aptamer(s), the conjugation, and nucleic acid in comparison with gp120 alone as immunogens are evaluated. Various aptamer complexes are injected into guinea pigs to provoke an immune response. For each experiment, three animals receive 0.05 ml (50 – 100 µg) of vaccine in subcutaneous injection. Two booster immunizations take place at 3-week intervals, and animals are bled 10-28 days after immunizations. Serum antibodies against gp120 is quantified initially by gp120 ELISA (Moore *et al.*, 1989).

EXAMPLE 7Cell-based HIV neutralization assays

[00153] Neutralization assays are performed using U87.CD4.CCR5 cells (available from the NIH AIDS Research Reagent Database) (Bjornal *et al.*, 1997 and Richman *et al.*, 2003) transiently transfected with HIV-1 LTR driven β-galactosidase, and the non-fluorescent fluorogenic substrate, 5-chloromethylfluoroscein di-β-D-galactopyranoside (CMFDG) (Molecular Probes) in a single cycle HIV-1 infection assay. HIV infection results in expression of Tat which transactivates expression of the β -galactosidase gene which can be detected *via* production of fluorescein. Each dilution is tested in triplicate. Pre-immune sera is also tested as a control for nonspecific neutralization. An HIV-1 BaL strain is available for single cycle infectivity assays from Advanced Bioscience Laboratories (Gaithersburg, MD). Viruses (50-100 50% tissue culture infective dose) in 50 µl of RPMI complete medium containing 20 U of interleukin-2 (Hoffman-LaRoche) is pre-incubated with an equal volume of serially diluted heat-inactivated sera (35 min at

56 °C) for 10 minutes at room temperature. This mixture is then incubated in 96-well flat bottom plates with transfected U87.CD4.CCR5 cells for 48 hours at 37 °C to allow for a single cycle of infection and production of β-galactosidase. Production of β-galactosidase can then be measured by addition of the fluorogenic substrate CMFDG and quantification of fluorescein fluorescence in a Packard Fusion fluorescence plate reader. Each dilution is tested in triplicate. Pre-immune sera is also tested as a control for nonspecific neutralization.

EXAMPLE 8In vitro Assays for Evaluating Aptamer Stability

[00154] Serum stabilities of aptamers are assayed *in vitro* as described (Green *et al.*, 1995). Briefly, 5'-<sup>32</sup>P end-labeled aptamers are incubated at 2 nM in human serum at 37° C. Reactions are terminated at specific time points by addition of 87% formamide and analyzed for percent degradation by denaturing PAGE.

EXAMPLE 9Coupled Selection

[00155] In one embodiment, the selection for gp120 specific binding aptamers can be facilitated by linking the RNA pool to a capture (oligonucleotide) probe attached at the end of a spacer (*e.g.*, a PEG spacer). The probe-spacer is attached to either a monoclonal antibody with a known locus specificity on gp120, or directly to gp120. In this manner, a low affinity aptamer that is capable of inducing a conformational shift in gp120 can be more easily identified. In one embodiment, the probe-spacer is linked to a gp120-specific binding monoclonal antibody or fragment thereof through linking chemistries to the glycosyl residues on the antibody or fragment through linkers and linking methods known in the art. In one embodiment, the probe-spacer is linked directly to gp120 by linking to glycosyl residues on gp120 using the same linkers and linking chemistries also known in the art.

[00156] By pre-coupling pools to gp120, the initial requirements for high affinity binders are removed and aptamers that can mimic CD4 but have low intrinsic gp120 affinity can be enriched. Using monoclonal antibodies of known epitopes to attach the RNA pool to gp120 also provides an indication of where to engineer in a cysteine mutation for final covalent coupling of aptamer and gp120 in subsequent vaccine trials.

Monoclonal antibodies or Fab fragments thereof that are chosen are non-neutralizing and do not interfere with either receptor or co-receptor binding. This method is compatible with activity based selection methods.

[00157] References cited above by author and year of publication are given their full citation below, and is each herein incorporated by reference in its entirety.

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[00158] The invention having now been described by way of written description and examples, those of skill in the art will recognize that the invention can be practiced in a variety of embodiments and that the foregoing description and examples are for purposes of illustration and not limitation of the following claims.

What is claimed is:

- 1) A composition comprising gp120 and a nucleic acid aptamer that binds to gp120 and induces gp120 to undergo a conformational shift whereby an epitope to a membrane bound receptor is exposed that is capable of eliciting a humoral immune response.
- 2) The composition of Claim 1 wherein the epitope to the membrane bound receptor is an epitope to CCR5.
- 3) The composition of Claim 1 wherein the epitope to the membrane bound receptor is an epitope to CXCR4.
- 4) The composition of Claim 1, 2 or 3 wherein the nucleic acid aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 5) A method of vaccinating a subject against HIV infection comprising administering to a subject a composition comprising gp120 and a nucleic acid aptamer that binds to and induces gp120 to undergo a conformational shift whereby an epitope to a membrane bound receptor is exposed that is capable of eliciting a humoral immune response.
- 6) The method of Claim 5 wherein the epitope to the membrane bound receptor is an epitope to CCR5.
- 7) The method of Claim 5 wherein the epitope to the membrane bound receptor is an epitope to CXCR4.
- 8) The method of claim 5, 6 or 7 wherein said nucleic acid aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 9) A method of producing neutralizing antibodies specific to gp120 comprising administering a composition comprising gp120 and a nucleic acid aptamer that binds to gp120 and induces gp120 to undergo a conformational change whereby an epitope to a membrane bound receptor is exposed that is capable of eliciting a humoral immune response.

- 10) The method of Claim 9 wherein the epitope to the membrane bound receptor is an epitope to CCR5.
- 11) The method of Claim 9 wherein the epitope to the membrane bound receptor is an epitope to CXCR4.
- 12) The method of claim 9, 10 or 11 wherein said nucleic acid aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 13) The method of Claim 9 wherein neutralizing antibodies are produced.
- 14) A method of treating HIV infection comprising the step of administering a composition comprising gp120 and a nucleic acid aptamer that binds to gp120 and induces gp120 to undergo a conformational change whereby an epitope to a membrane bound receptor is exposed that is capable of eliciting a humoral immune response.
- 15) The method of Claim 14 wherein the epitope to the membrane bound receptor is an epitope to CCR5.
- 16) The method of Claim 14 wherein the epitope to the membrane bound receptor is an epitope to CXCR4.
- 17) The method of claim 14, 15 or 16 wherein said nucleic acid aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 18) An aptamer that binds to gp120 selected from SEQ ID No. 9 through SEQ ID No. 225.
- 19) A composition comprising an aptamer that binds to gp120 selected from SEQ ID No. 9 through SEQ ID No. 225.
- 20) An aptamer that binds to gp120 complexed to gp120, wherein said aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.

- 21) A method of treating HIV infection in a subject comprising administering a therapeutically effective amount of an aptamer that binds gp120 selected from SEQ ID No. 9 through SEQ ID No. 225.
- 22) A method of treating HIV infection in a subject comprising administering a therapeutically effective amount of an aptamer that binds to gp120 complexed to gp120, wherein said aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 23) A method of preventing HIV infection in a subject comprising administering a prophylactically effective amount of an aptamer that binds to gp120 complexed to gp120, wherein said aptamer is selected from SEQ ID No. 9 through SEQ ID No 225.
- 24) A method of producing neutralizing antibodies with specificity to HIV gp120 comprising administering an aptamer that binds to gp120 complexed to gp120, wherein said aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 25) A method of eliciting a humoral immune response in a subject resulting in neutralizing antibodies specific gp120 comprising administering an aptamer that binds to gp120 complexed to gp120, wherein said aptamer is selected from SEQ ID No. 9 through SEQ ID No. 225.
- 26) A method for identifying an aptamer that binds to gp120 and induces gp120 to undergo a conformational change whereby an epitope to a membrane bound receptor is exposed that is capable of eliciting a humoral immune response comprising the steps of:
  - (a) synthesizing aptamers with spacers from about 20 to about 200 Angstrom spacers ending in a primary amine moiety;
  - (b) generating single free thiols on cysteine mutations in the N termini, C termini and/or the non-neutralizing face of gp120;
  - (c) covalently attaching said aptamers with a crosslinker to said free thiols on gp120; and
  - (d) screening aptamers for binding to a gp120 epitope.

27) A method for identifying an aptamer that binds to gp120 and induces gp120 to undergo a conformational change whereby an epitope to a membrane bound receptor is exposed that is capable of eliciting a humoral immune response comprising the steps of:

- (a) synthesizing aptamers with spacers from about 20 to about 200 Angstrom spacers ending in a primary amine moiety;
- (b) generating single free thiols on cysteine mutations in an antibody or antibody fragment that binds to gp120;
- (c) covalently attaching said aptamers with a crosslinker to said free thiols on the antibody or antibody fragment; and
- (d) screening aptamers for binding to a gp120 epitope.

28) The method of Claim 26 or 27 wherein said spacer is polyethylene glycol.

29) The method of Claim 26 or 27 wherein said crosslinker is a hetero-bifunctional crosslinker

30) The method of Claim 29 wherein said hetero-bifunctional crosslinker is Sulfo-LC-SPDP (sulfosuccinimidyl 6-[3'-(2-pyridylidithio)-propionamido] hexanoate).

31) The method of Claim 30 wherein said gp120 epitope is selected from CCR5 and CXCR4.

32) The method of Claim 26 or 27 wherein said screening is performed with gp120 BaL mutants and said screening is performed with CCR5 peptides or full CCR5 receptor.

33) An aptamer comprising a first binding domain which recognizes a first ligand coupled to a second binding domain which recognizes a second ligand wherein binding of the second ligand by the second binding domain is regulated by binding of the first ligand by the first binding domain.

34) The aptamer of Claim 33, wherein the first ligand binding domain specifically interacts with an allosteric effector molecule and the second ligand binding domain specifically interacts with a target of the allosteric effector molecule.

- 35) The aptamer of Claim 34, wherein the allosteric effector molecule is gp120 and the target is the CCR5 receptor.
- 36) The aptamer of Claim 33, wherein binding of the second ligand by the second binding domain is activated by binding of the first ligand by the first binding domain.
- 37) The aptamer of Claim 34, wherein binding of the second ligand by the second binding domain is activated by binding of the first ligand by the first binding domain.
- 38) The aptamer of Claim 33, wherein binding of the second ligand by the second binding domain is suppressed by binding of the first ligand by the first binding domain.
- 39) The aptamer of Claim 34, wherein binding of the second ligand by the second binding domain is suppressed by binding of the first ligand by the first binding domain.
- 40) A method of selecting regulated aptamers comprising the steps of isolating first and second aptamers which bind first and second ligands, respectively, using SELEX, engineering a diverse sequence pool of molecules that contain the binding domains of the first and second aptamers, and selecting for regulated aptamers from that pool wherein binding of the second ligand by the second binding domain is regulated by binding of the first ligand by the first binding domain.
- 41) A method of treating HIV in a subject comprising the steps of administering a therapeutically effective amount of an CCR5 receptor aptamer, wherein said CCR5 receptor aptamer binds to a gp120 effector and is activated by the gp120 effector to bind to said CCR5 receptor, and preventing gp120 binding to cells.

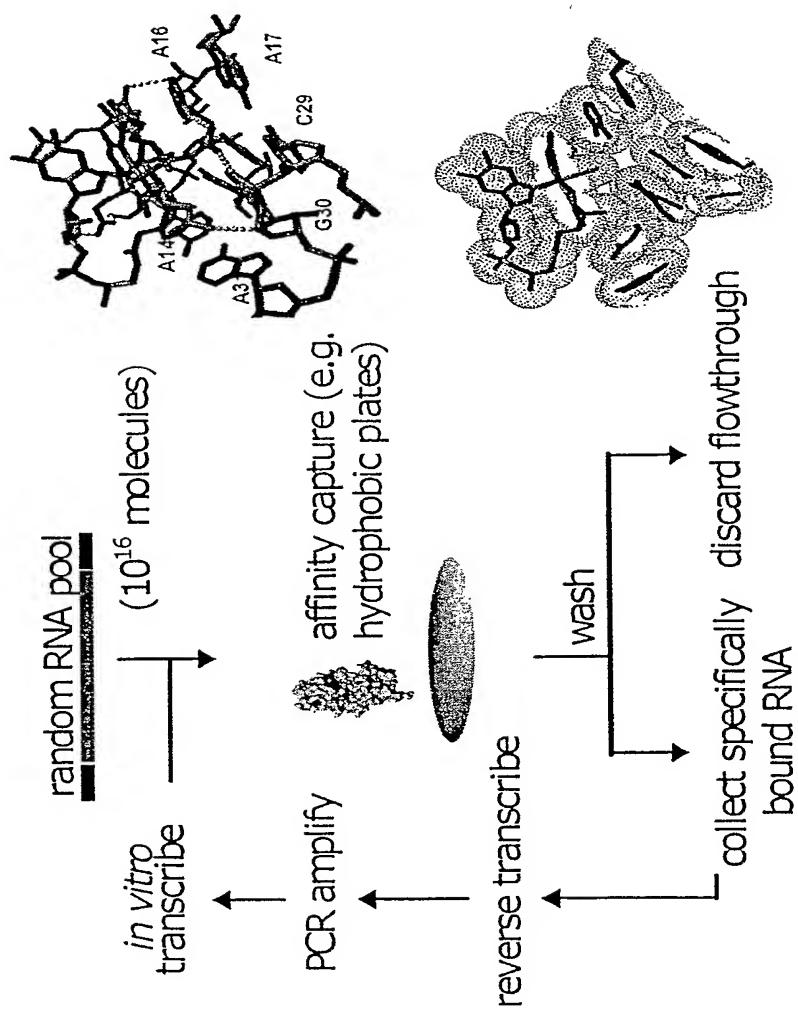


Figure 1

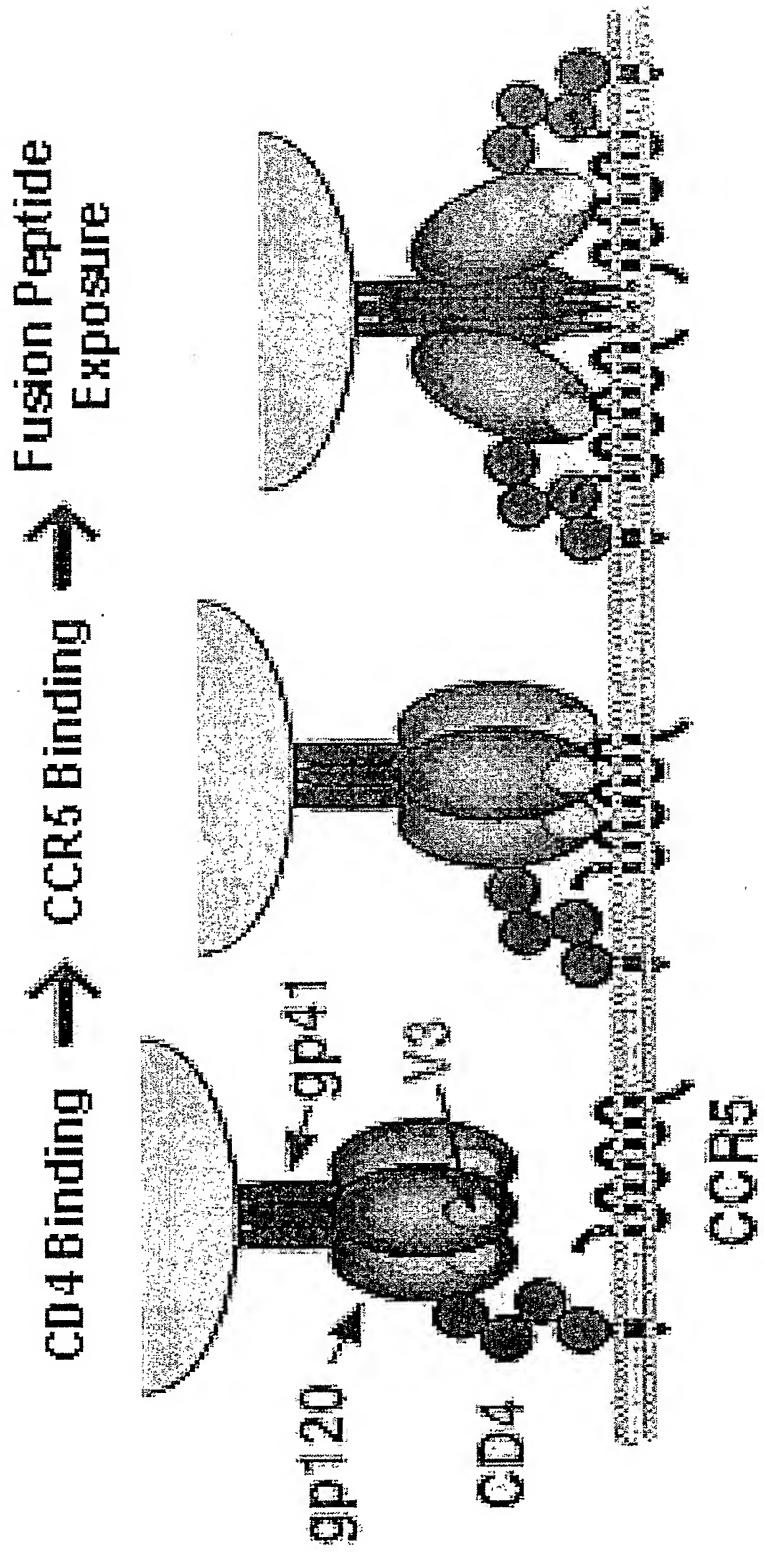


Figure 2

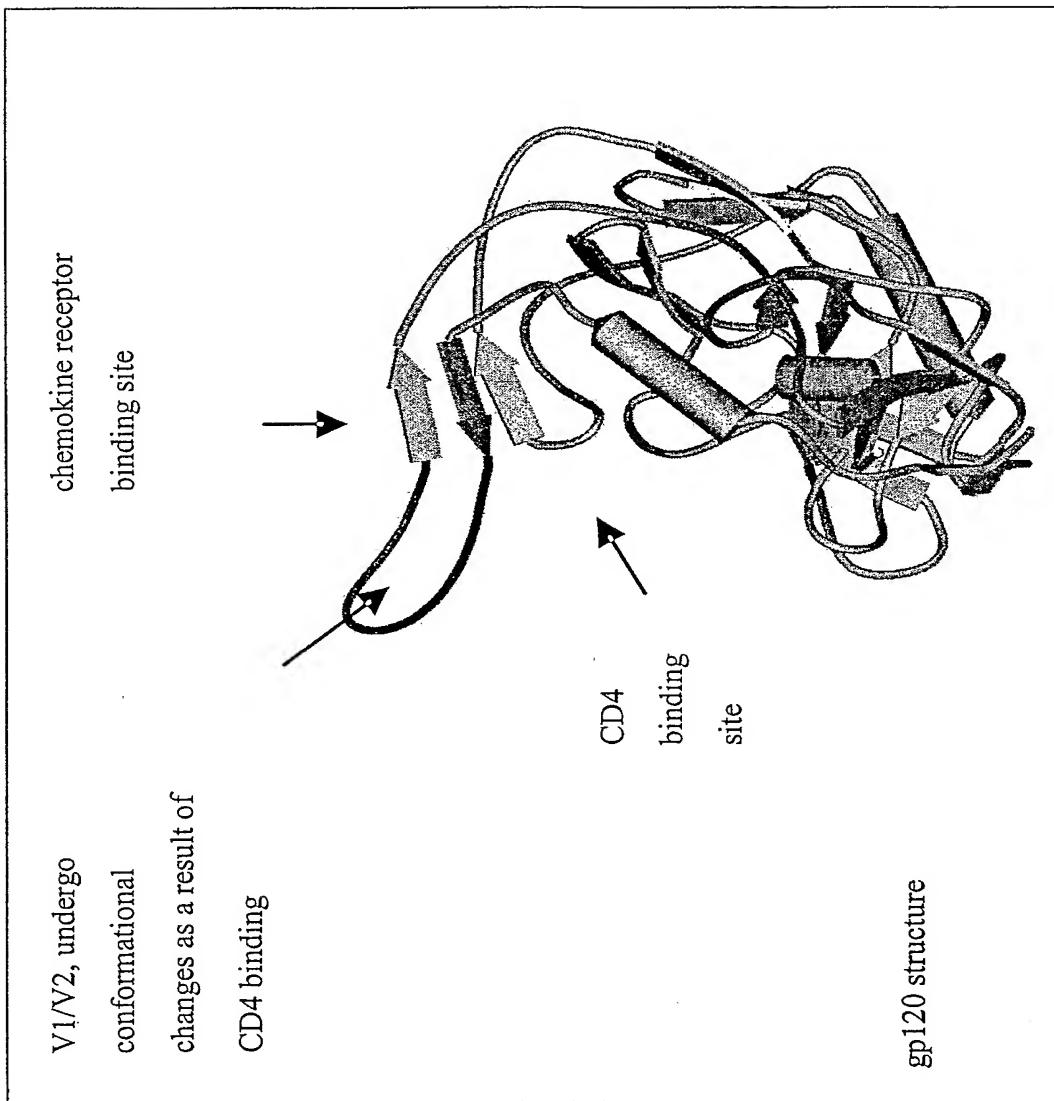


Figure 3

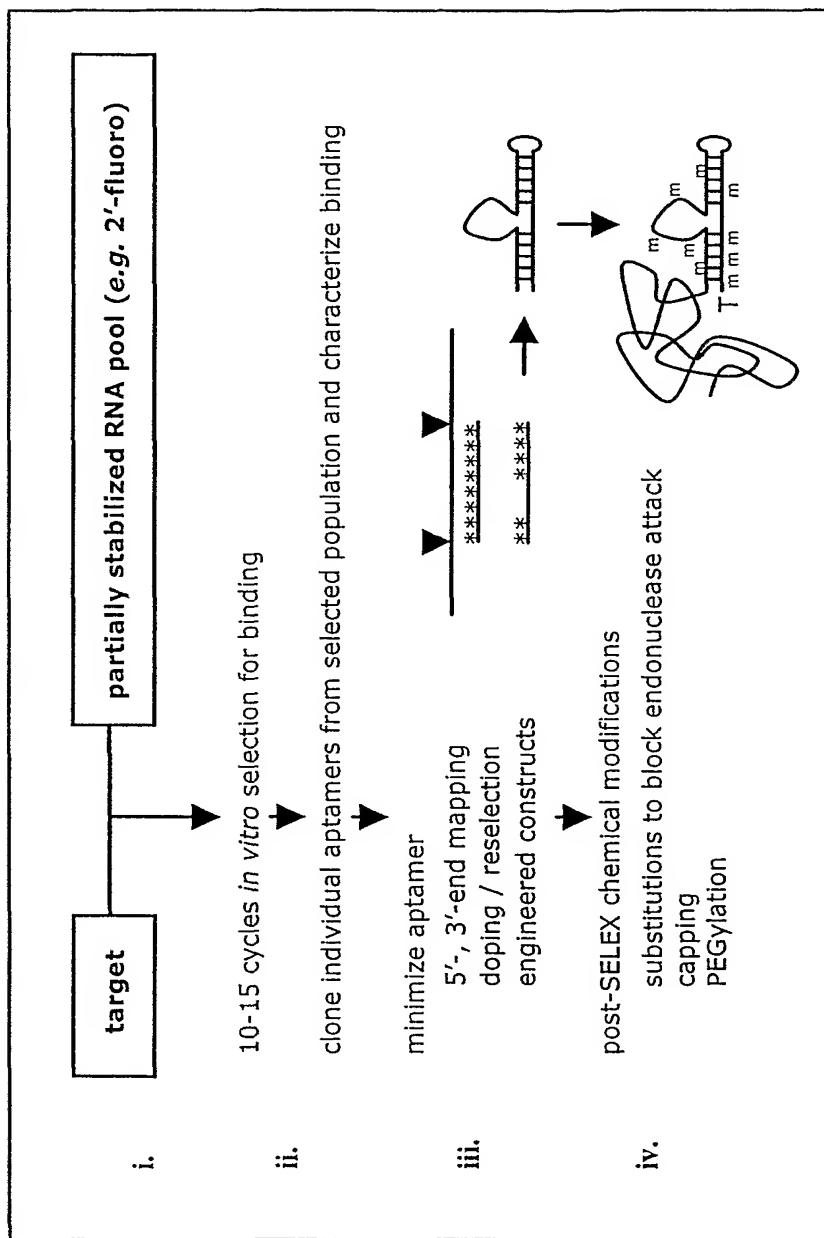


Figure 4

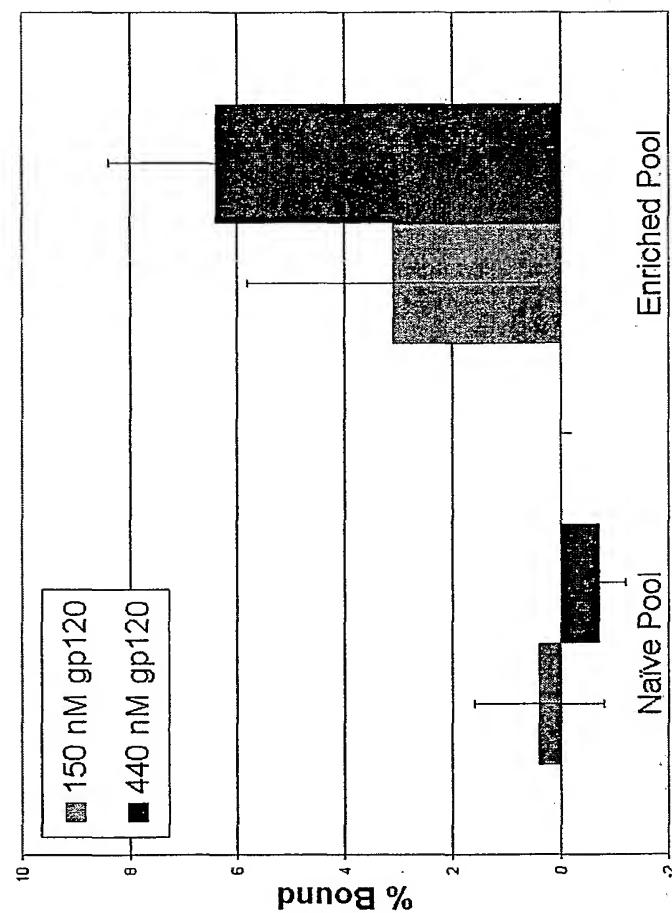


Figure 5

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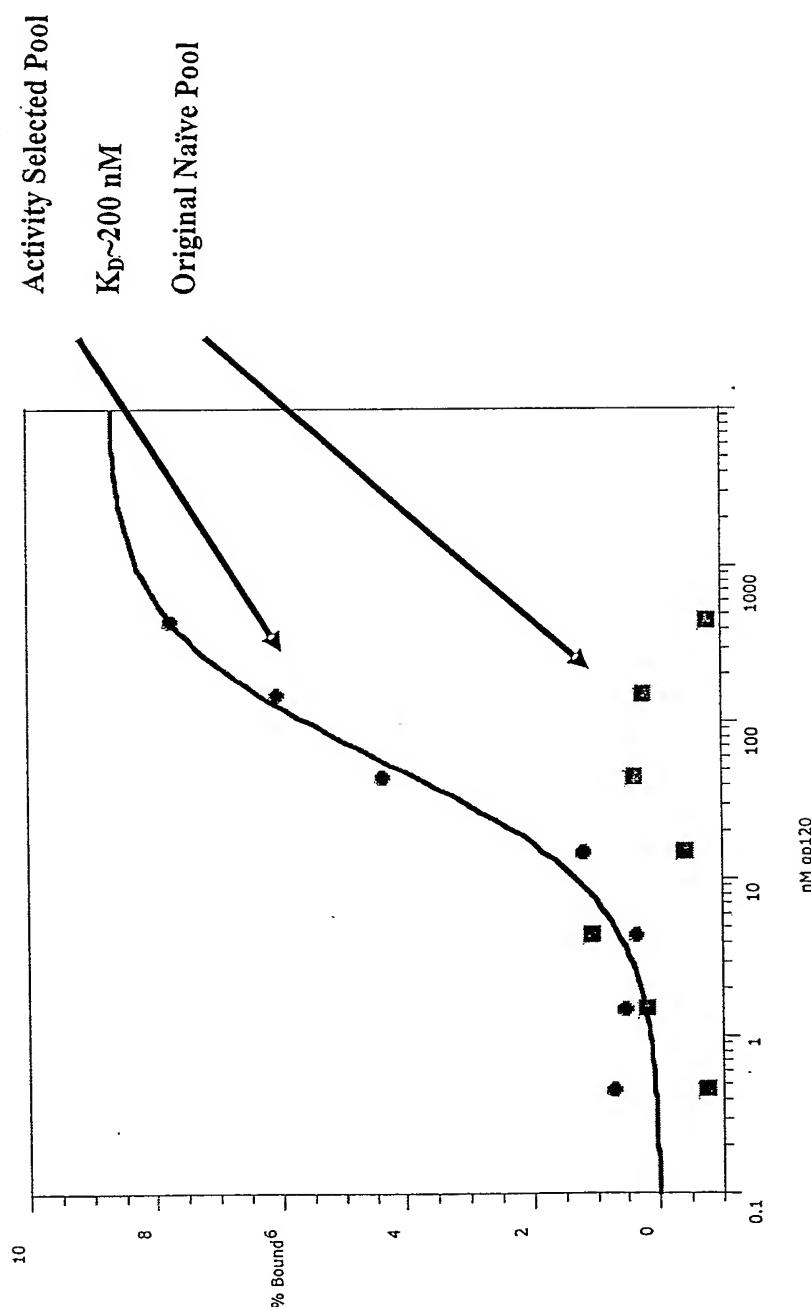


Figure 6

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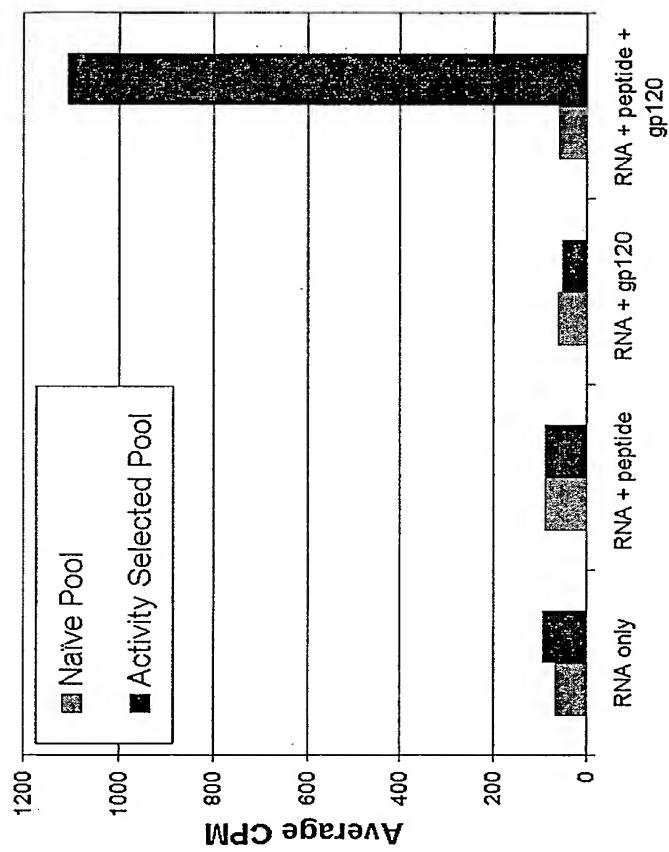


Figure 7

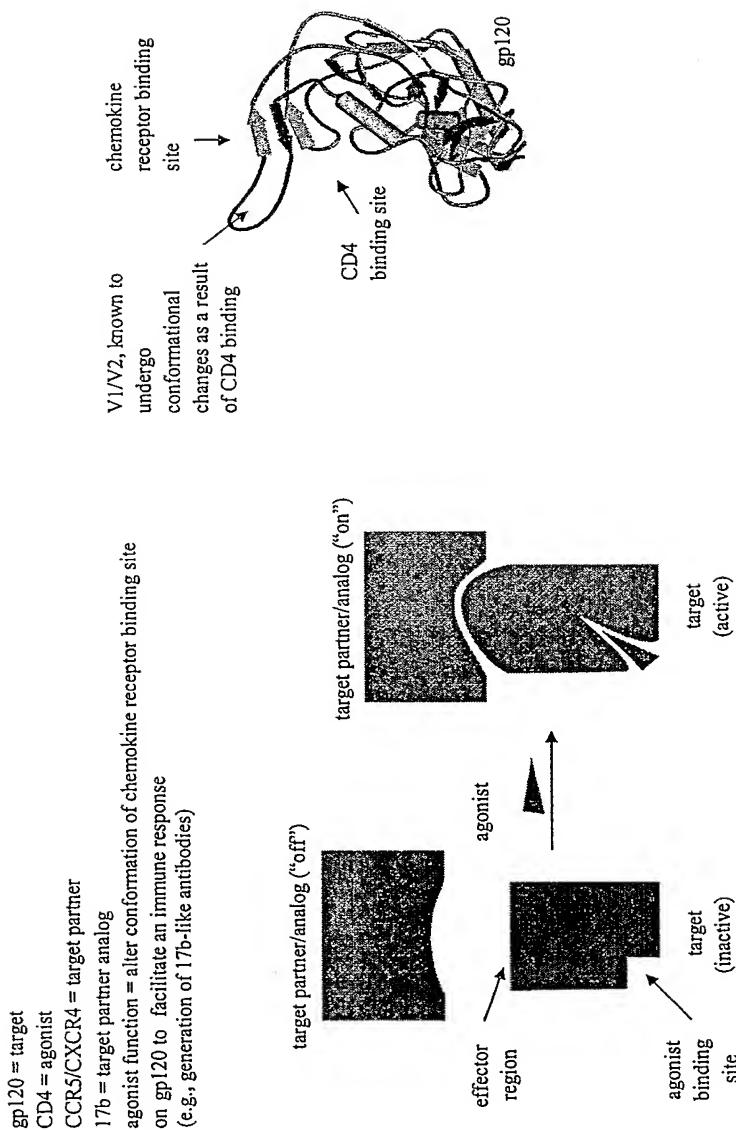


Figure 8

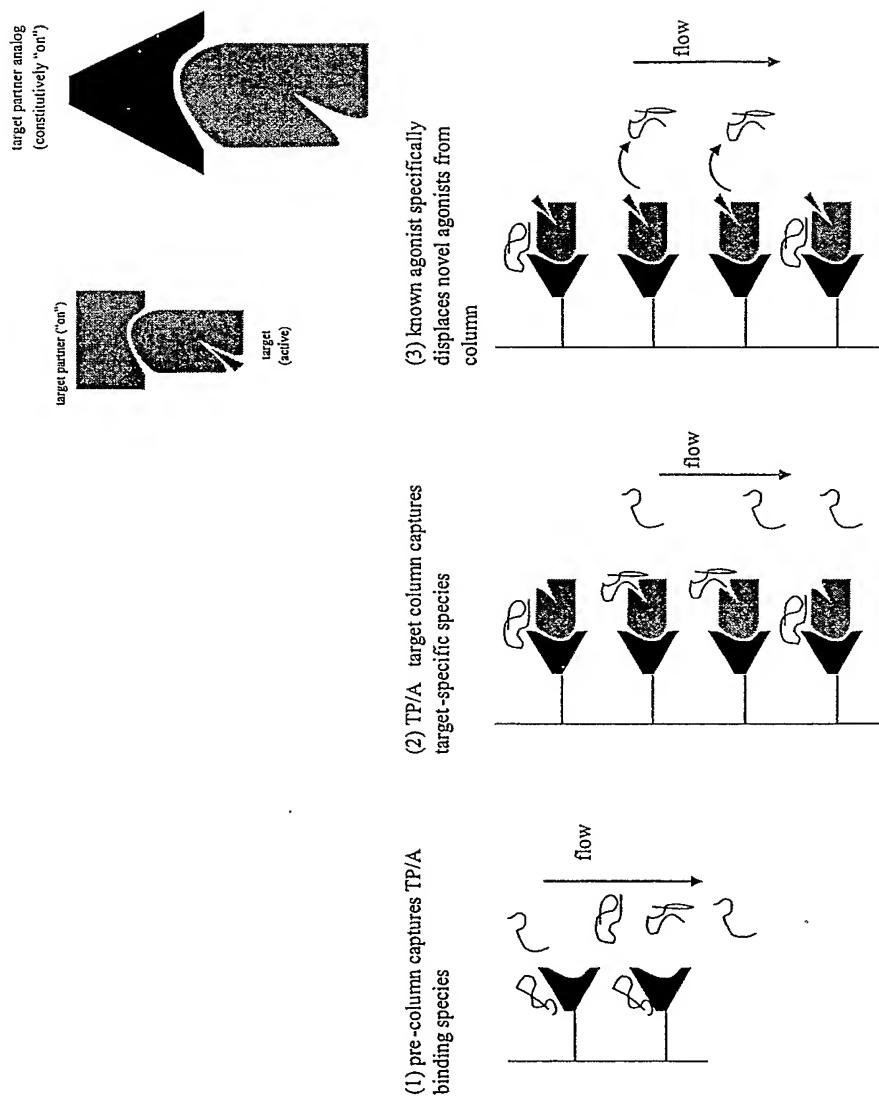


Figure 9

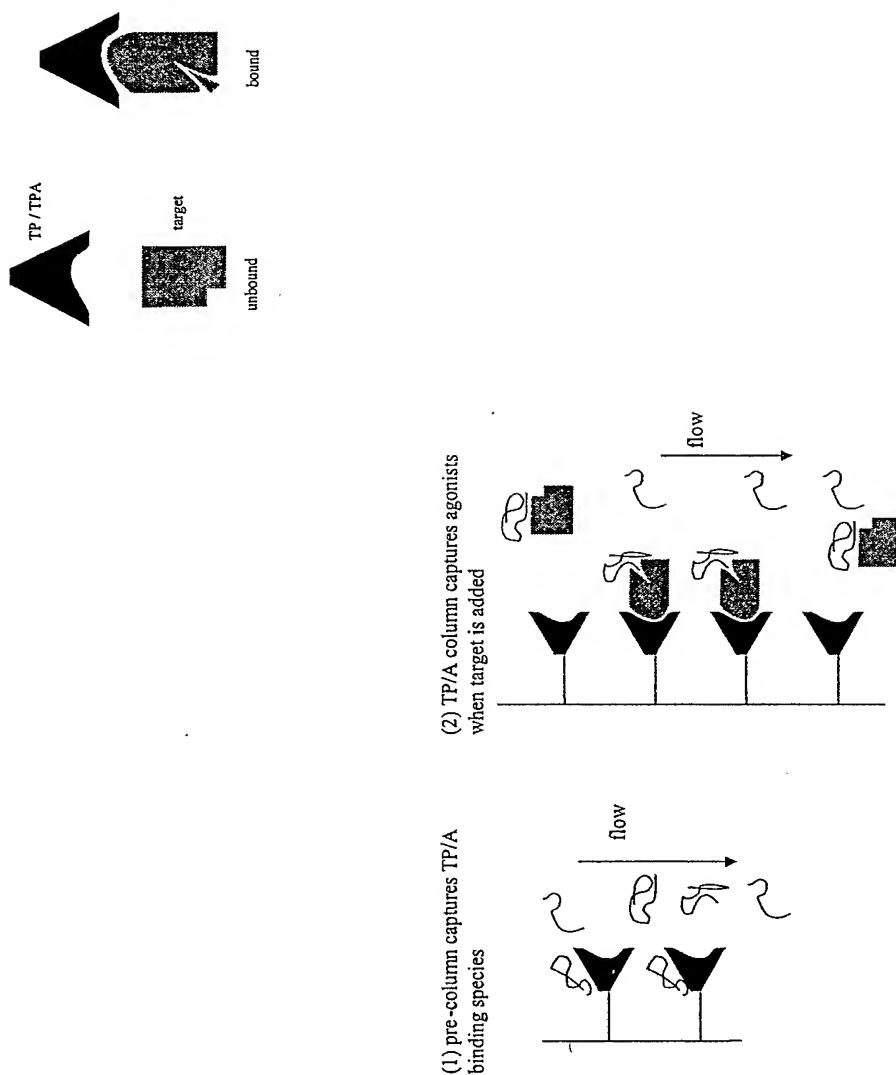
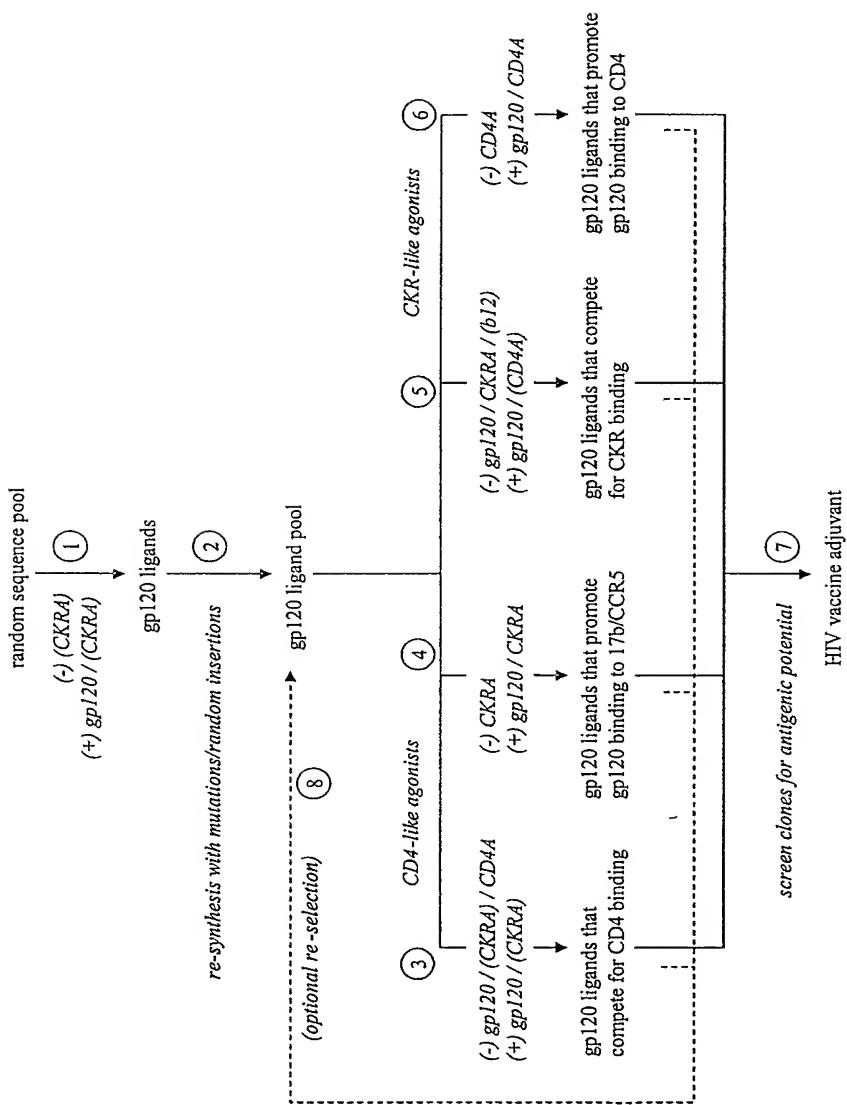


Figure 10

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**Figure 11**

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Figure 12